

Illustration courtesy of F. Chavez/K. Lance
(Monterey Bay Research Institute/MBARI)

Illustration by Kelly Lance © MBARI 2013



NATIONAL MARINE SANCTUARIES

MBON

Marine Biodiversity
Observation Network

...from microbes to whales



Integrated Ocean Observing System

Why measure biodiversity?



Biodiversity benefits:

ecosystem function & resilience,
chemical cycles,
human health (food, materials, chemicals,
recreation)

Understanding life and why it has evolved on Earth

Life in the Sea

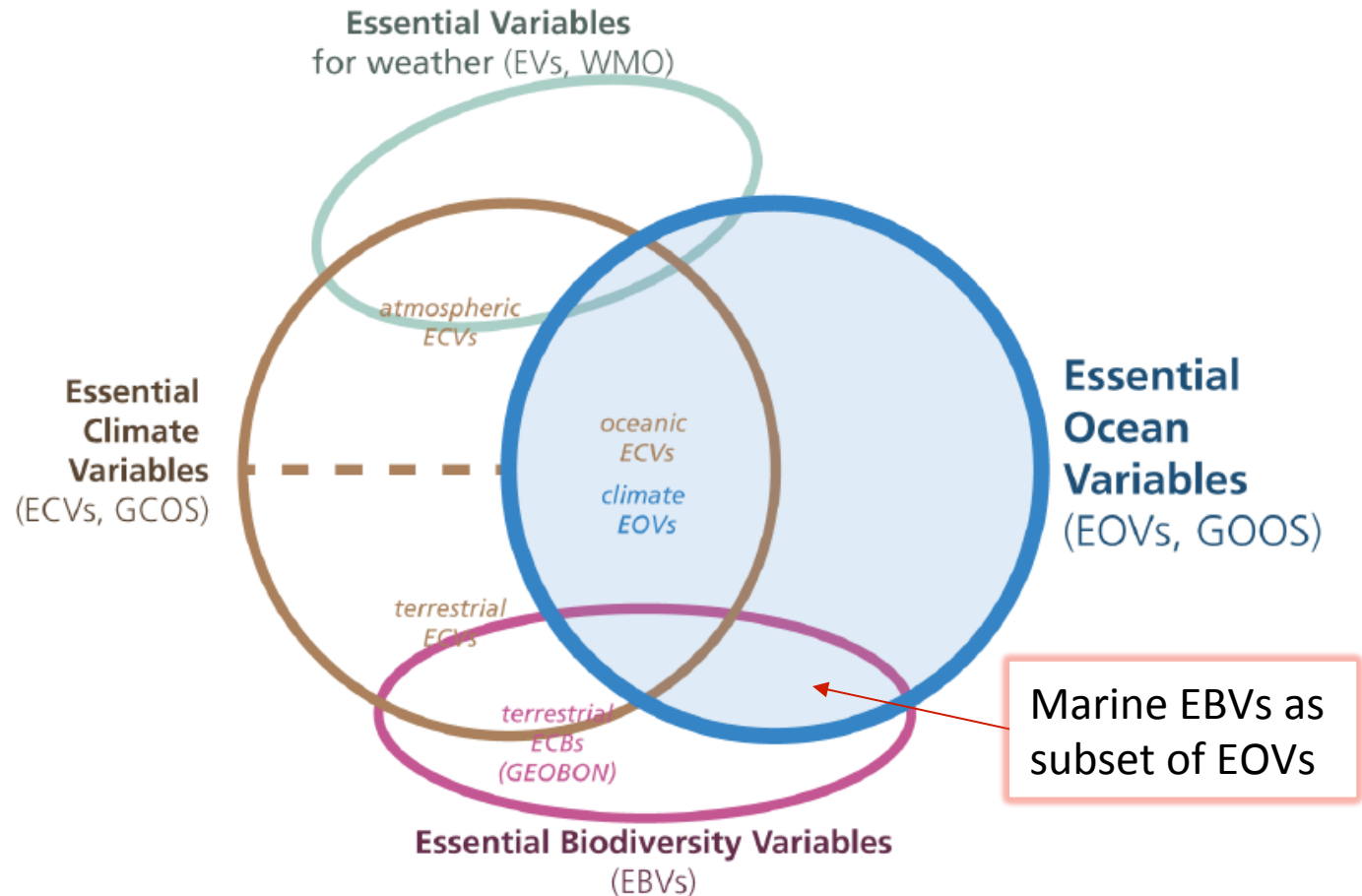


Biodiversity: the variety of life and habitats

- number of species,
- abundance, biomass, and distribution
- interactions (organisms & environment),
- variability of habitat

*These 'Essential Biodiversity Variables'
are really basic, but are very difficult to make*

Essential Variables: EOVS and EBV



- GOOS: GOOS panels (EOV)
- Group on Earth Observations (GEO): GEOBON – MBON
- National / academic programs

Need to be linked, and enabled to measure life



Essential Ocean Variables

Readiness level: **CONCEPT** | **PILOT** | **MATURE**

PHYSICS	BIOGEOCHEMISTRY	BIOLOGY AND ECOSYSTEMS
Sea state	Dissolved Oxygen	Phytoplankton biomass and diversity
Ocean surface vector stress	Inorganic macro nutrients	Zooplankton biomass and diversity
Sea ice	Carbonate System	Fish abundance and distribution
Sea surface height	Transient tracers	Marine turtles, birds, mammals abundance and distribution
Sea surface temperature	Suspended particulates	Live coral
Subsurface temperature	Nitrous oxide	Seagrass cover
Surface currents	Carbon isotope (^{13}C)	Macroalgal canopy
Subsurface currents	Dissolved organic carbon	Mangrove cover
Sea surface salinity	Ocean Colour (<i>Spec Sheet under development</i>)	Note: Many organisms have a planktonic phase
Subsurface salinity		
Heat flux / radiation		

Understanding life requires
EOV to be measured together



Priority for Demonstration Project:

→ Inform US National Marine Sanctuary Condition Reports

→ Contribute to develop an international MBON framework

eDNA Monitoring from Microbes to Whales

FLORIDA KEYS NATIONAL MARINE SANCTUARY



eDNA collection time series from MB & FK NMSs are allowing us to detect shifts in all trophic levels across these two diverse environments



MONTEREY BAY NATIONAL MARINE SANCTUARY



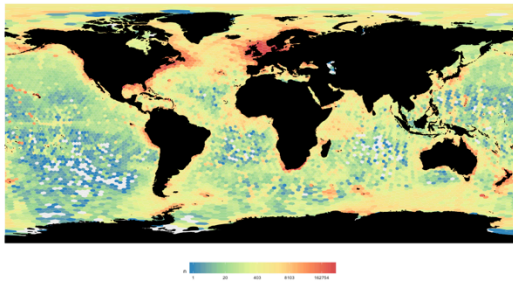
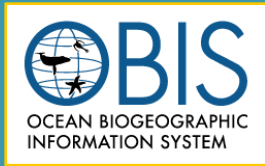
Monterey Bay National Marine Sanctuary
3000 Marina Drive, Suite 100
Marina, CA 93950
831.437.1000
<http://montereybay.nmfs.gov>

Sanctuary Information Center
3000 Marina Drive, Suite 100
Marina, CA 93950
831.437.1000
<http://montereybay.nmfs.gov>

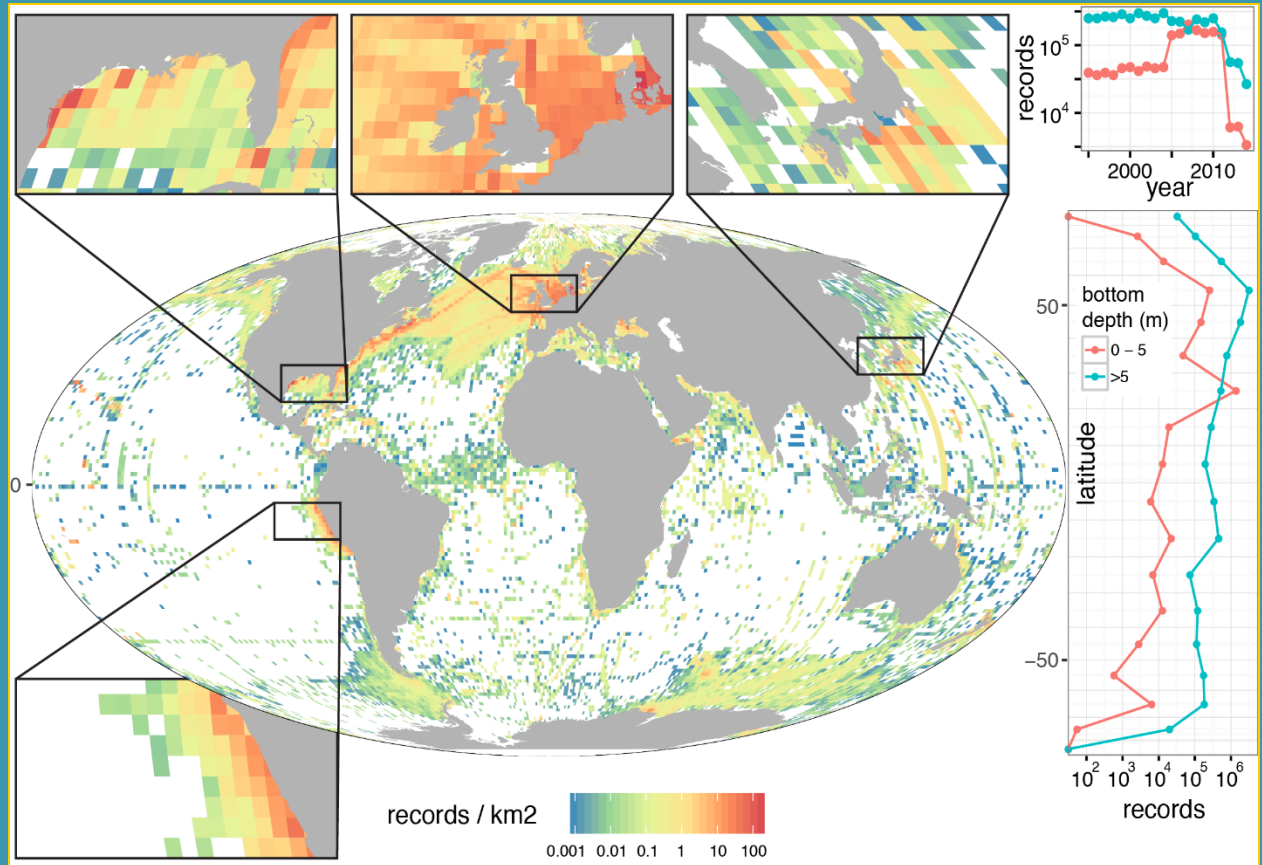
Coastal Watershed Center
3000 Marina Drive, Suite 100
Marina, CA 93950
831.437.1000
<http://montereybay.nmfs.gov>

Antiquities and Prescriptions
3000 Marina Drive, Suite 100
Marina, CA 93950
831.437.1000
<http://montereybay.nmfs.gov>

The state of marine biodiversity monitoring



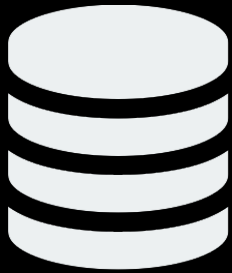
**OBIS: 47 million records
(water column to benthos)**



Near-surface taxonomic records (<20 m)

- Many areas have no records
- Less records in last 10 years:
lag in reporting data to OBIS

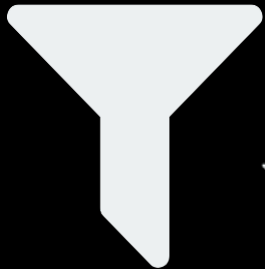
A collaborative NETWORK that links



Databases



Datasets



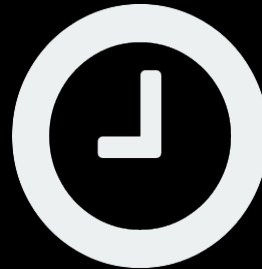
Filters:



Taxa



Space



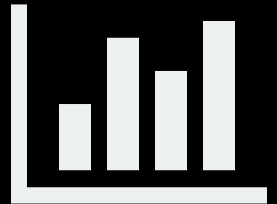
Time

To produce:

Maps



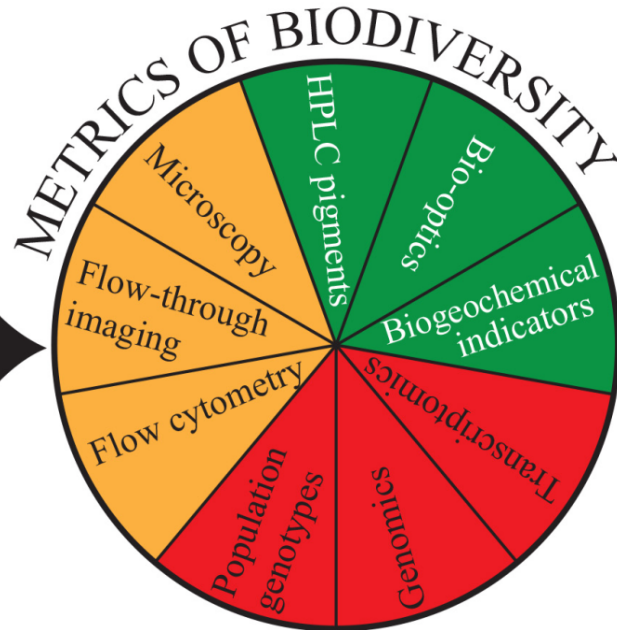
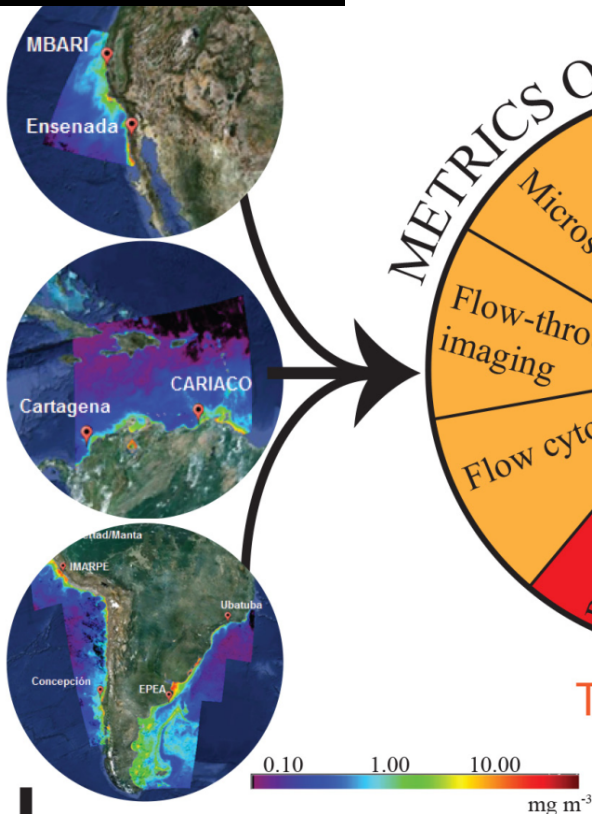
Abundance



Trends

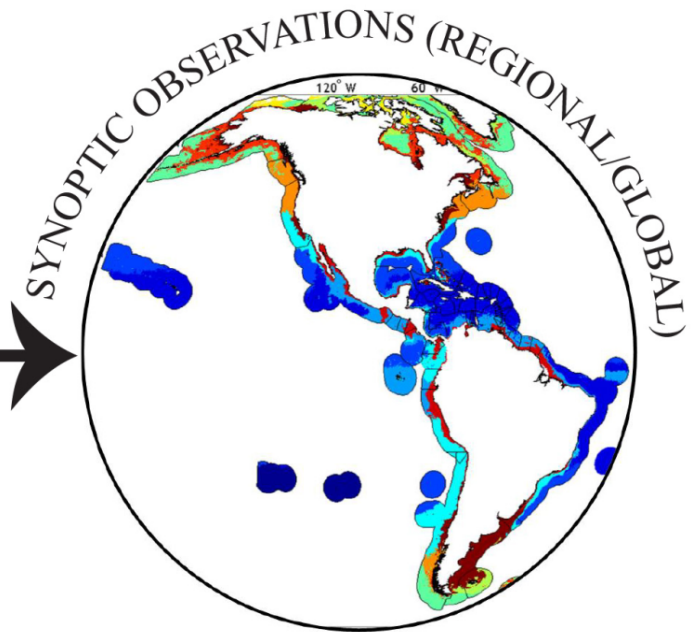


Time Series



TAXONOMIC DIVERSITY
GENOMIC DIVERSITY
FUNCTIONAL DIVERSITY

Seascapes



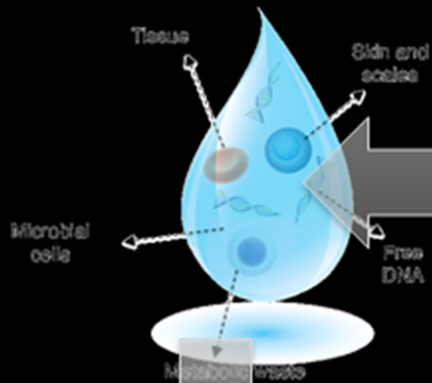
COLORS CORRESPOND
TO DISTINCT SEASCAPES

INTEGRATION

Assessment of impacts of disturbances on coastal biomes

Environmental Data Integration

eDNA testing



Autonomous eDNA
sensor

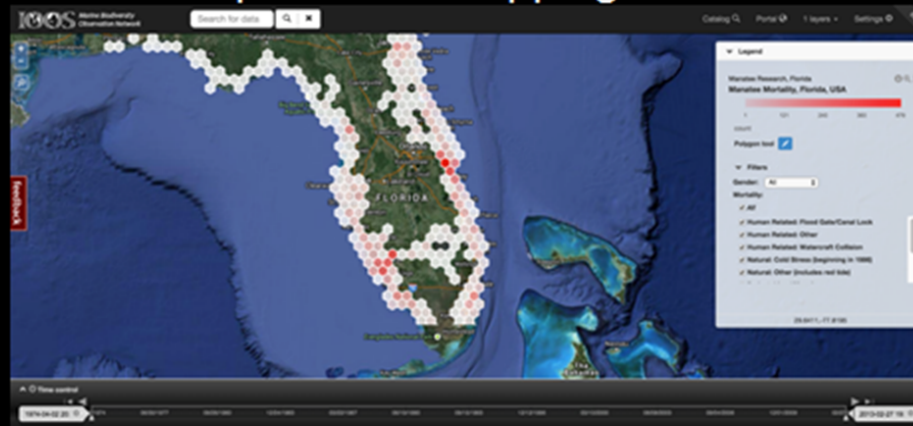


Case Studies

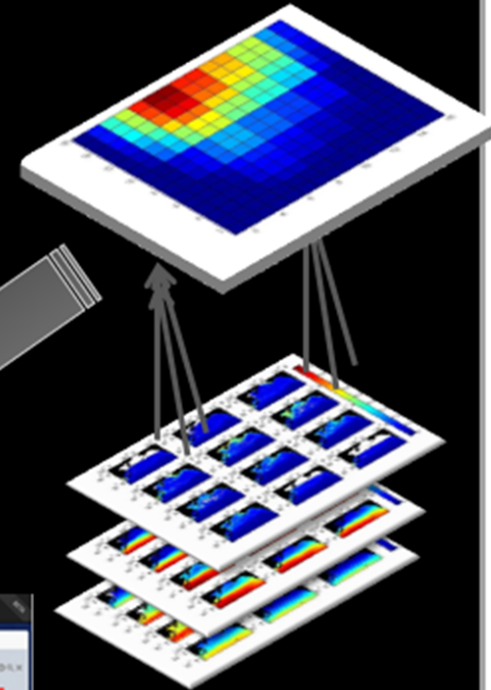
- Integration of 20y+ environmental and biological datasets
- In situ data collection

- E&O
- Socio-economics
- Ecosystem Valuation

MBON data
portal and mapping tool

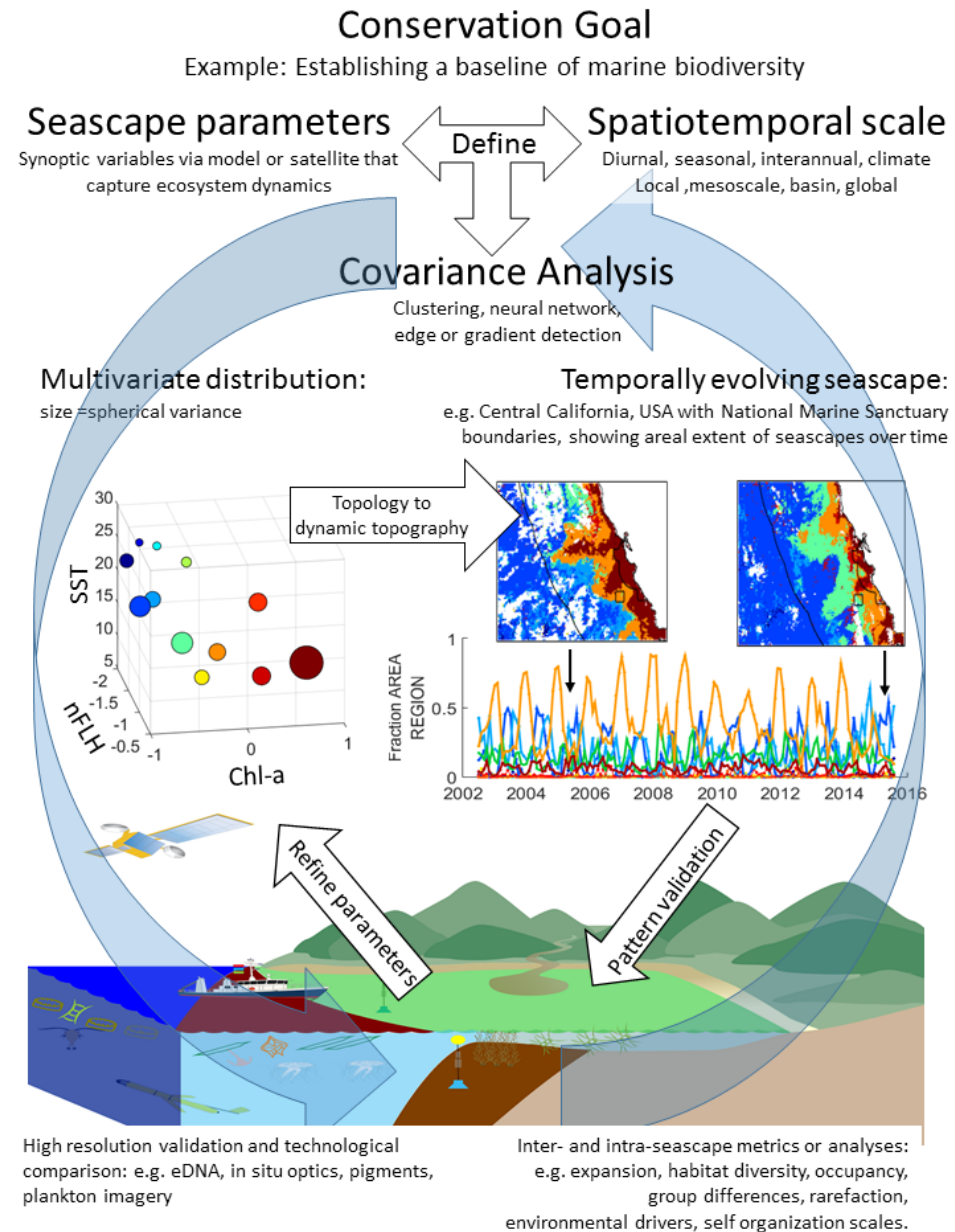


Ecological Marine Units Satellite Seascapes

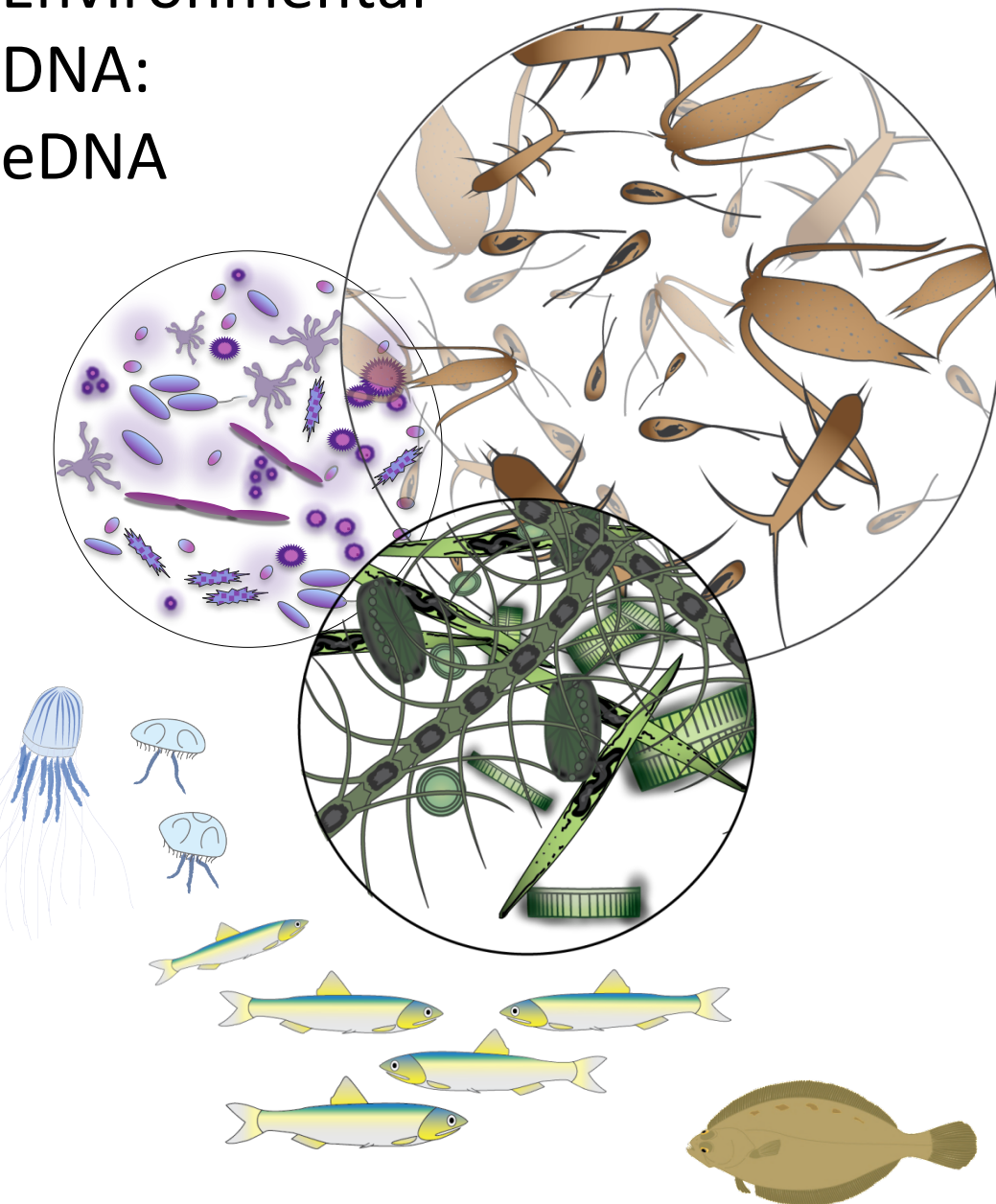


MBON and seascapes

- Biogeographic framework
- Seasonal and Interannual dynamics
- Ecosystem comparison
- Indicators and metrics
- Cruise planning, feature tracking

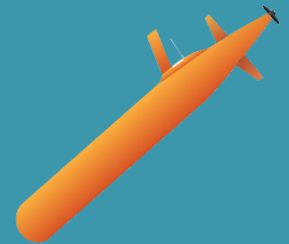


Environmental DNA: eDNA



eDNA allows detection
of diverse groups ...

using many platforms



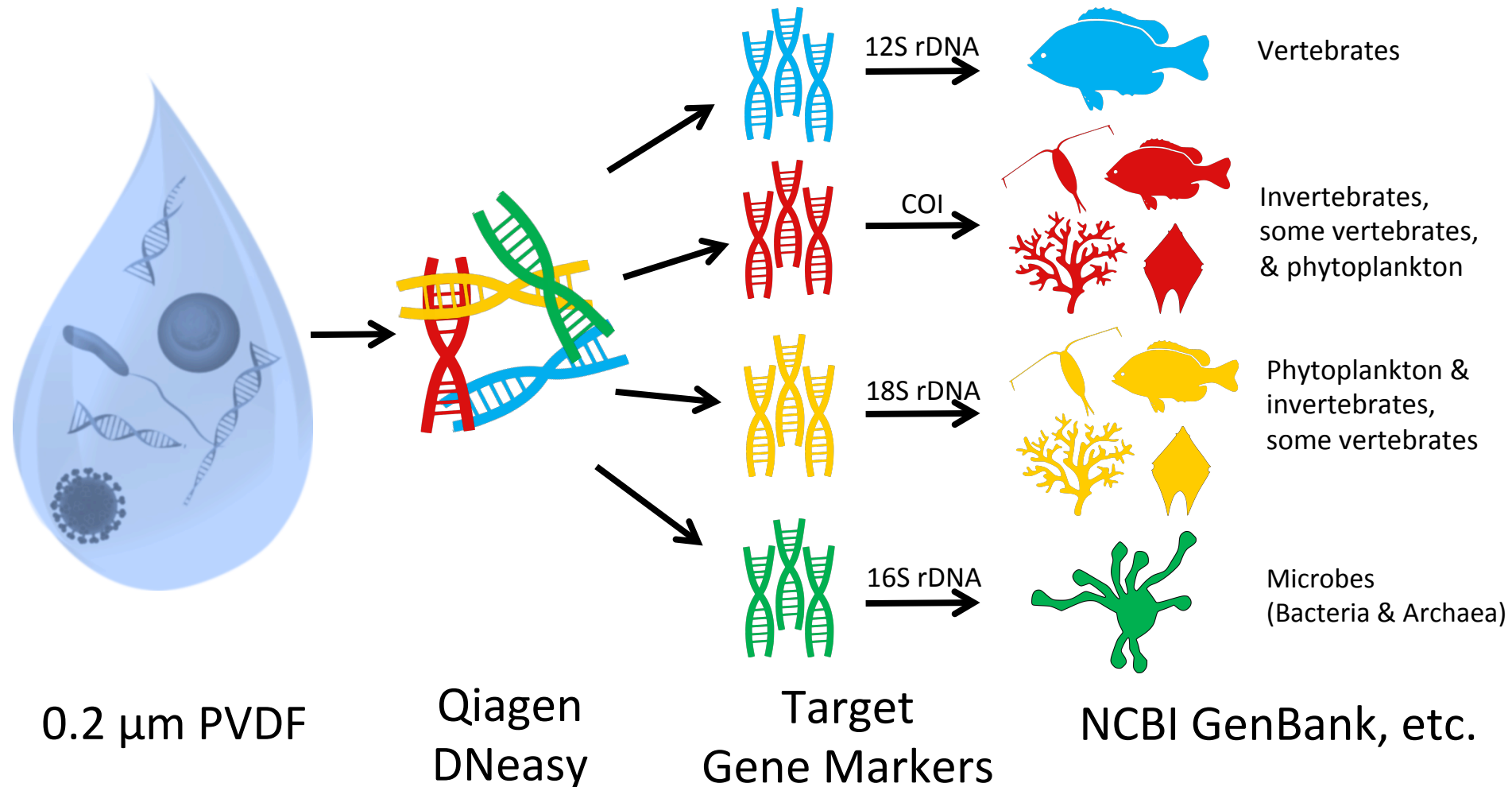
Milestone: MBON Standard Protocol

Filter 1L of
Seawater (x3)

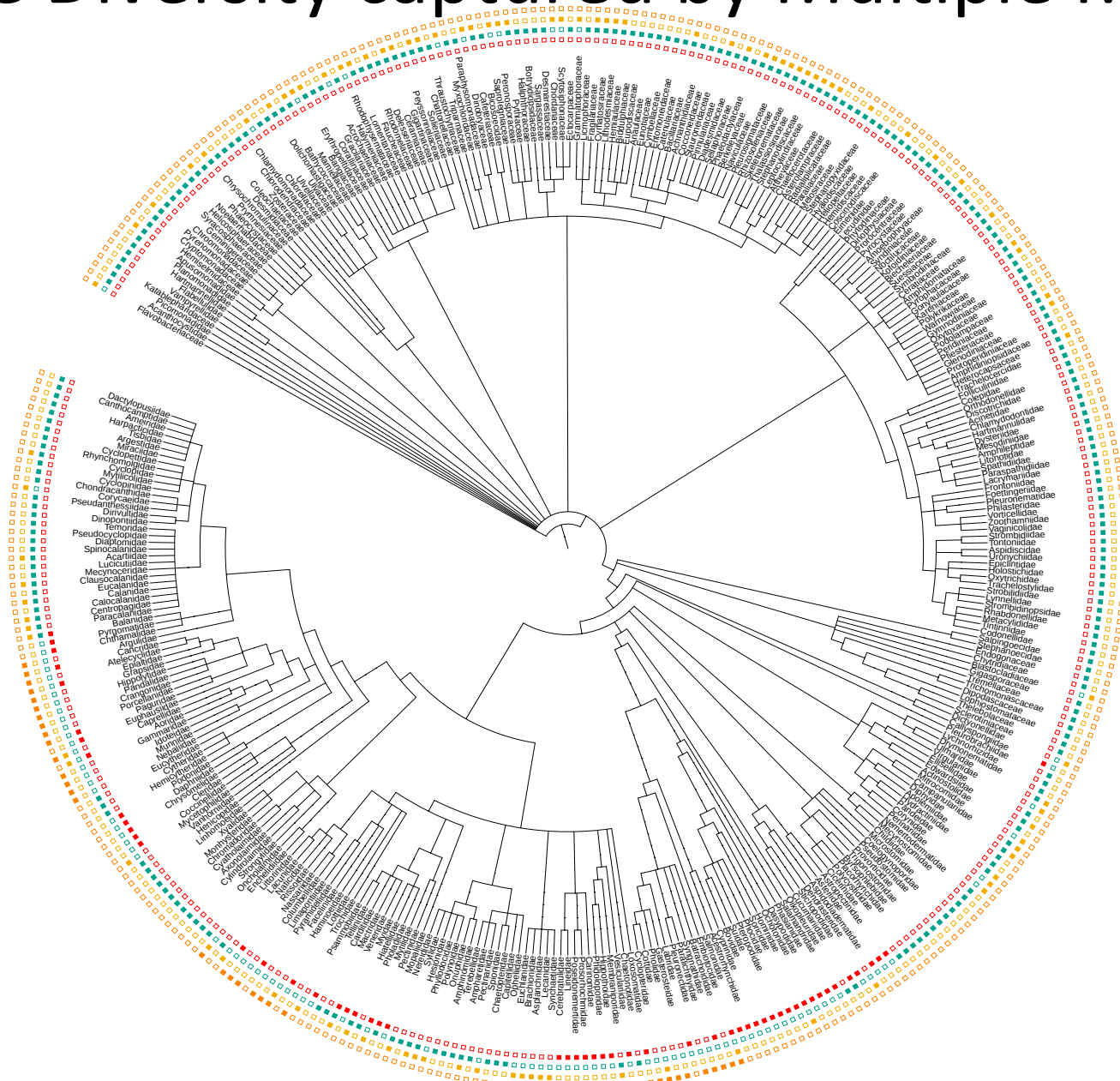
Extract
DNA

Amplify &
Sequence

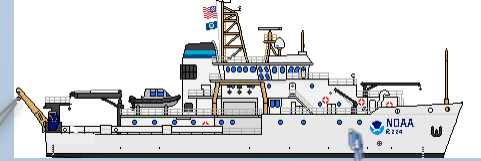
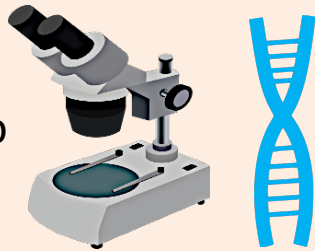
Identify Target
Organisms



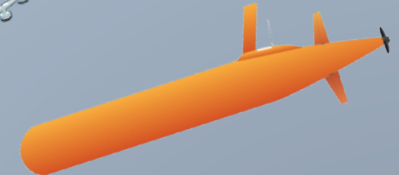
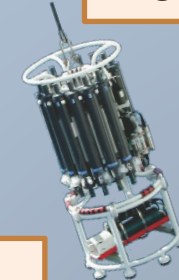
More Diversity captured by Multiple Markers



Compare microscope counts from net tows to CTD eDNA detections

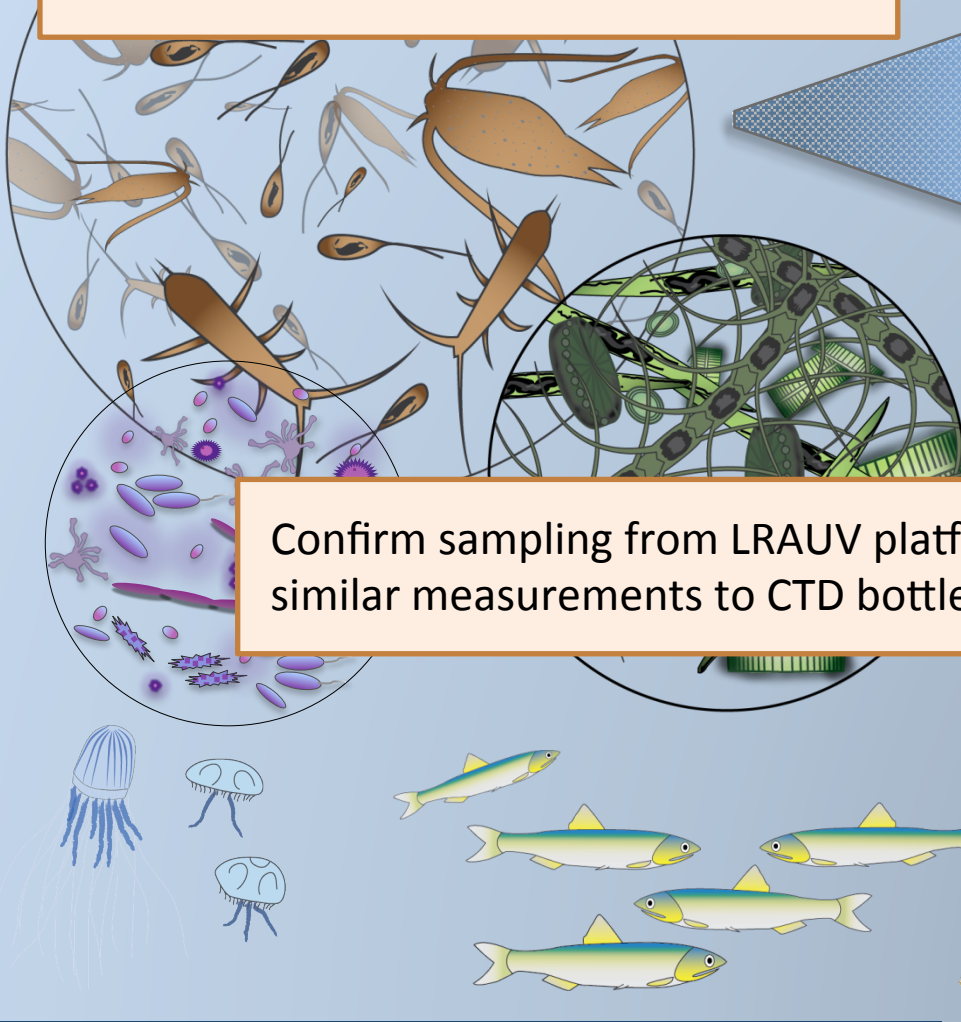


Paired CTD casts and net tows from MBARI, NOAA, academic Ships



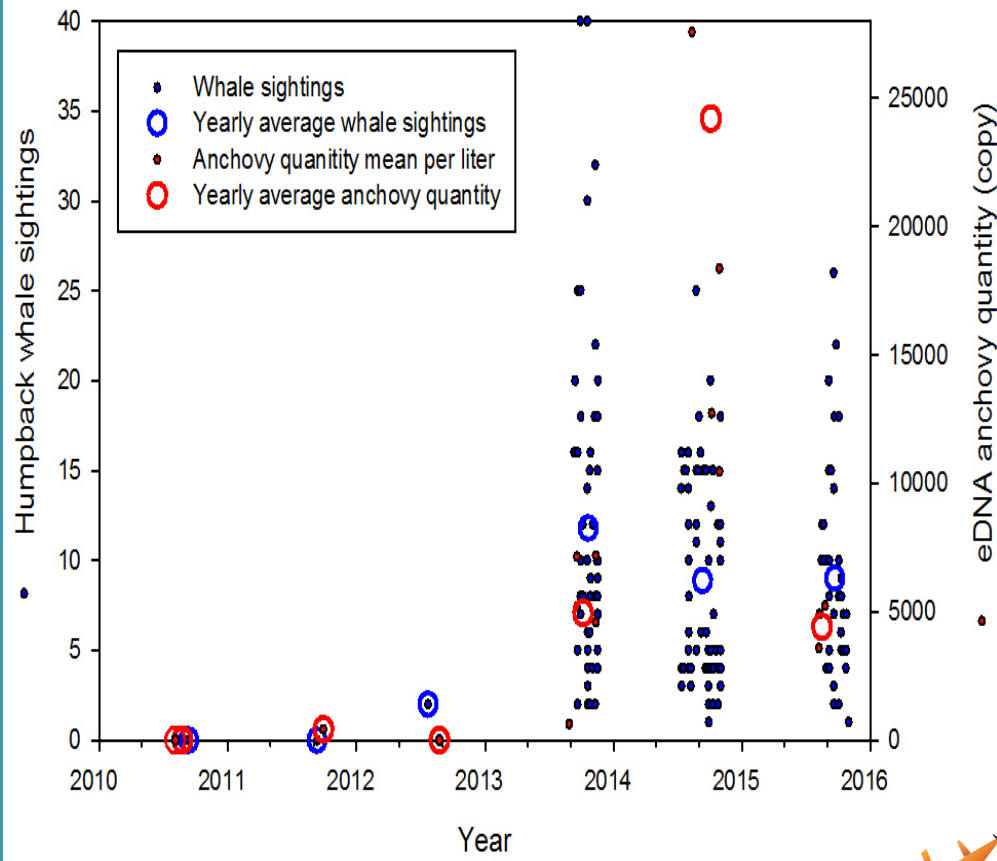
Confirm sampling from LRAUV platforms gives similar measurements to CTD bottle sampling

LRAUV automated sampling:
Environmental data, front detection, and 3G ESP samples



eDNA detected increased anchovy abundance

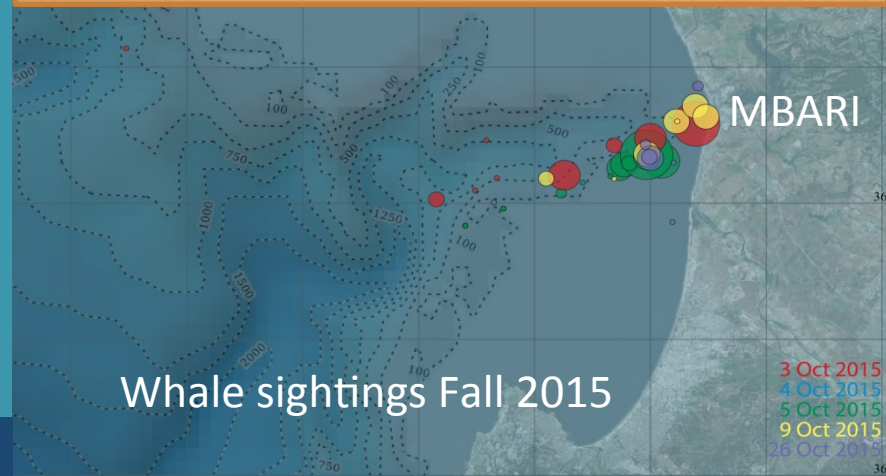
Monterey Bay, CA, station C1



In field trials 3G ESP successfully picked up anchovy eDNA



Preserved DNA samples allow the eDNA analysis of long time series – where other methods of analysis may be unavailable.



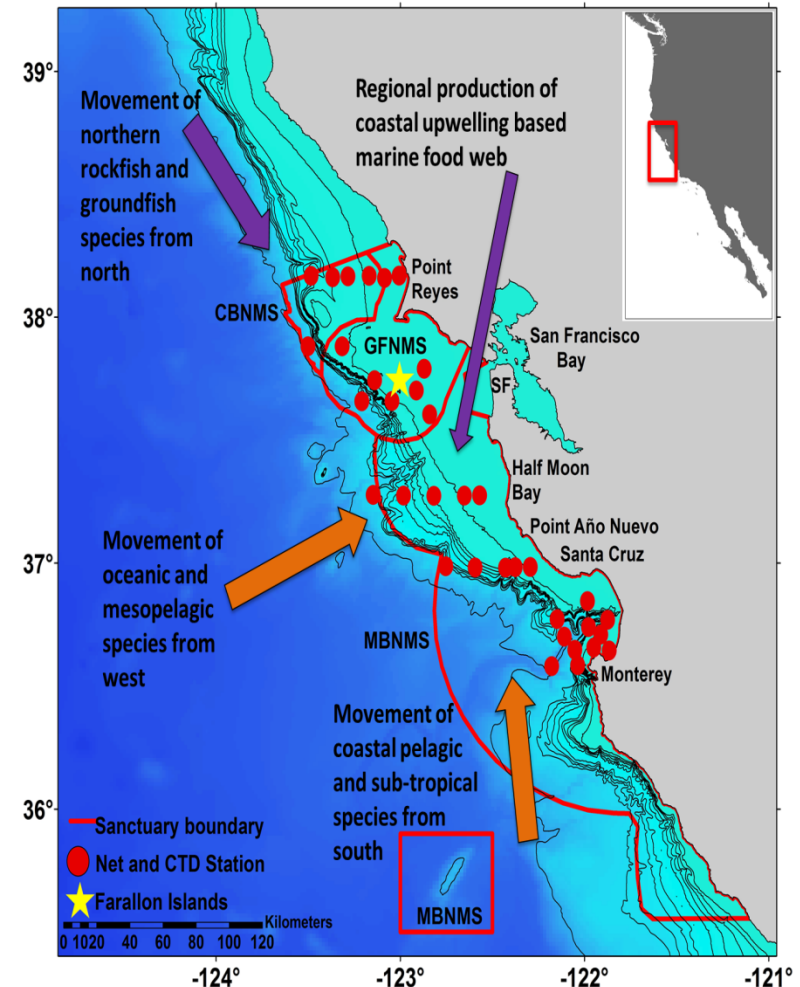
Whale sightings Fall 2015

3 Oct 2015
4 Oct 2015
5 Oct 2015
9 Oct 2015
26 Oct 2015

Impacts of ocean-climate variability on biodiversity of pelagic forage species within an upwelling ecosystem

Jarrood A. Santora, Elliott L. Hazen, Isaac D. Schroeder, Steven J. Bograd, Keith M. Sakuma, John C. Field

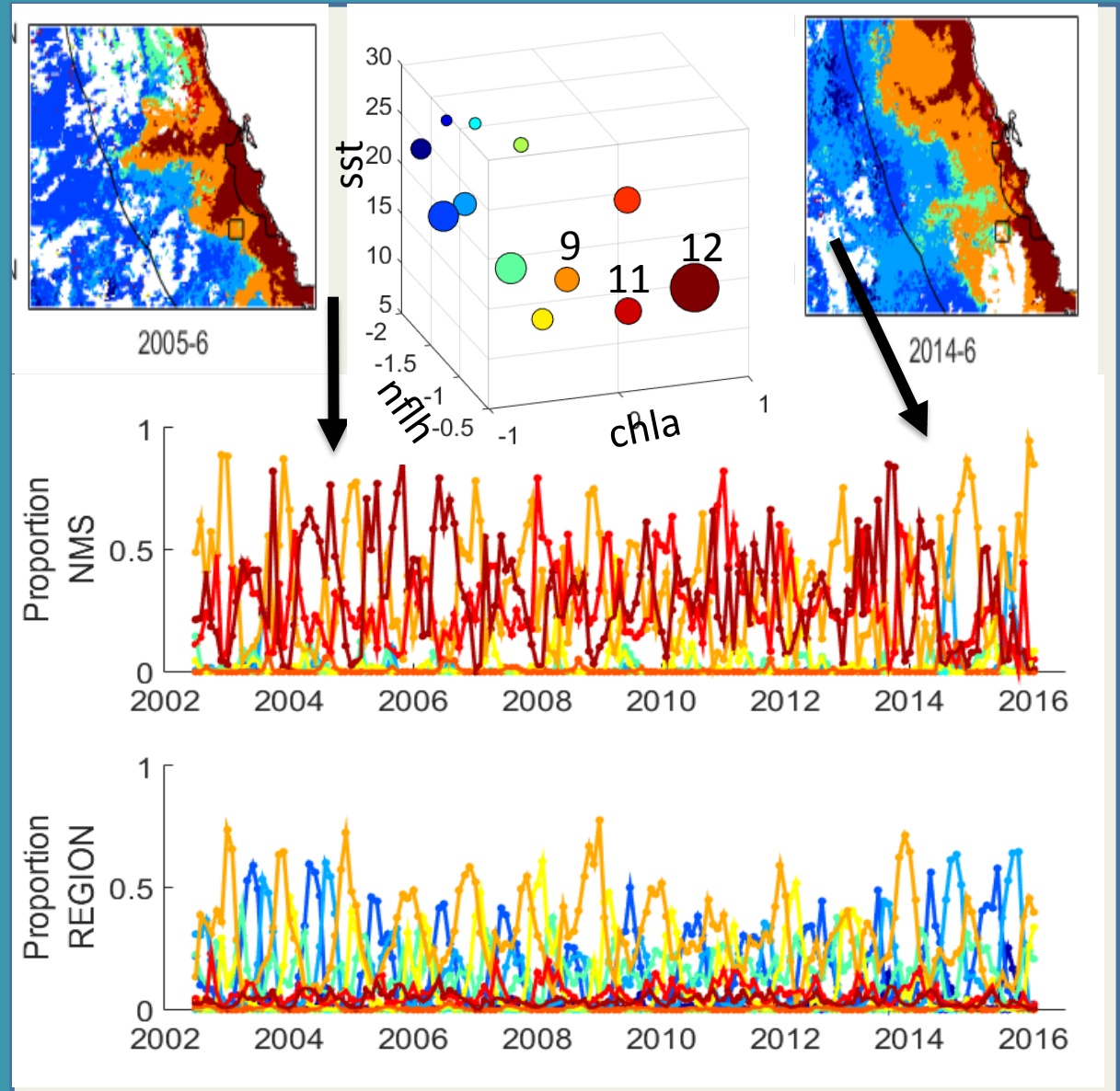
- Biodiversity time series using catch data from NOAA-NMFS juvenile rockfish survey
- Hosted on the U.S. MBON Portal <http://www.marinebon.org>
- Unusual biodiversity in 2015
- (Submitted to Marine Ecology Progress Series)



Pelagic habitat in the MBNMS

w/Jenn Brown & NMS

- Large interannual variability of typical CCS water (orange,9)
- Years of high and low productivity
- Fish diversity & distribution
- NMS Condition Reports

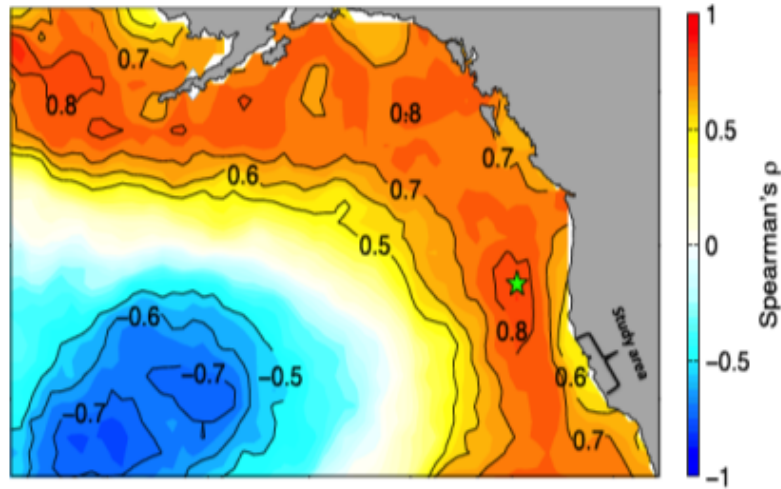


Central California pelagic forage fish and Eastern Pacific climate

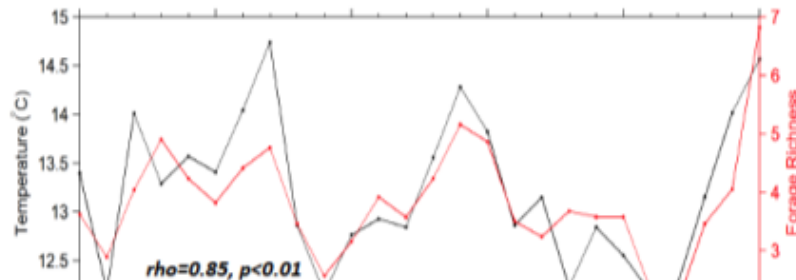
May-June SST & Forage Richness

Figure 7

High SST = High Forage Richness

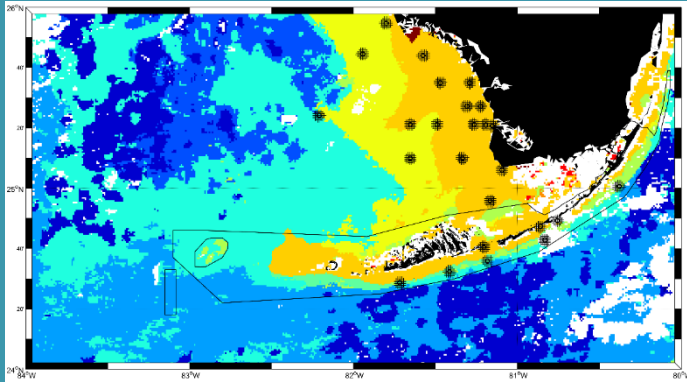


High PDO = High Forage Richness

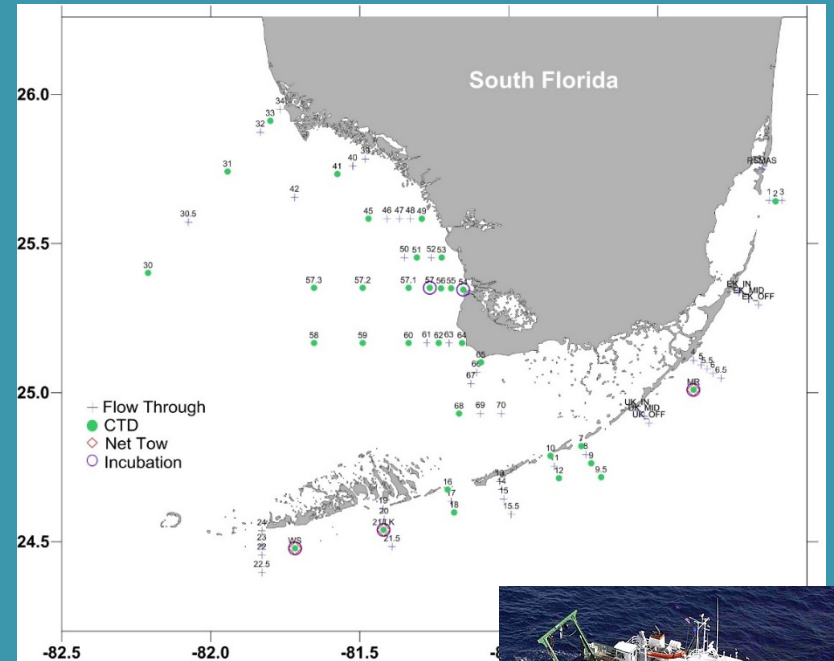
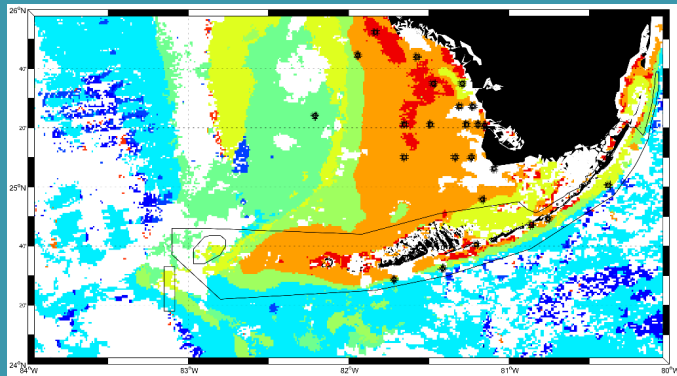


Florida Keys: Seascape validation of optics and microbial communities (Kavanaugh, Montes, Djurhuus, Otis)

March 14-18, 2016



May 9-13, 2016



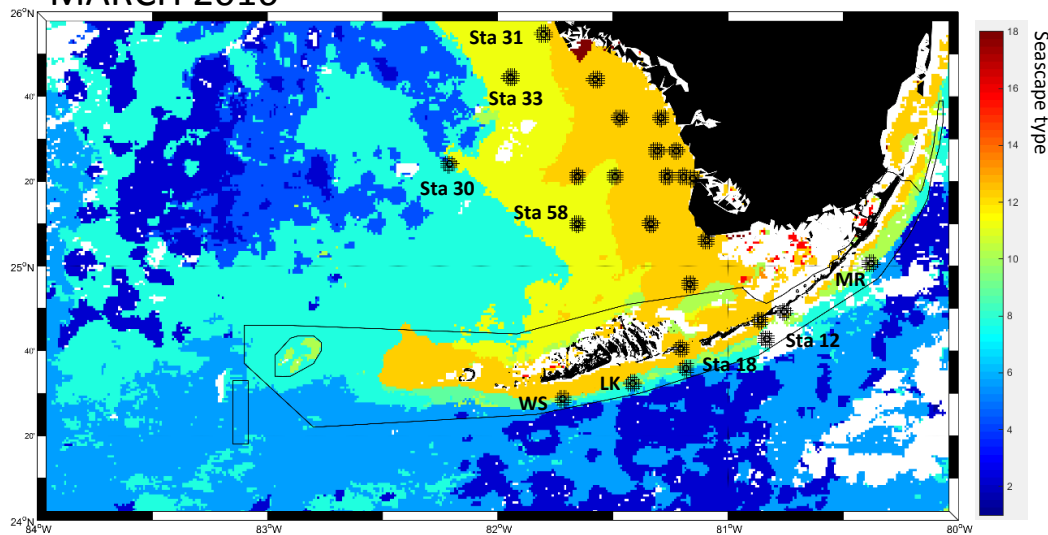
R/V Walton Smith (U. Miami)
MBON
South Florida Program (AOML)

In situ variables:

- Pigments (HPLC)
- Bio-optics (a_{phy})
- eDNA, genomics
- Zooplankton (64, 200, 500 μm)
- Phytoplankton taxa (microscopy)
- Environmental variables
(nutrients, temperature, salinity,
etc)

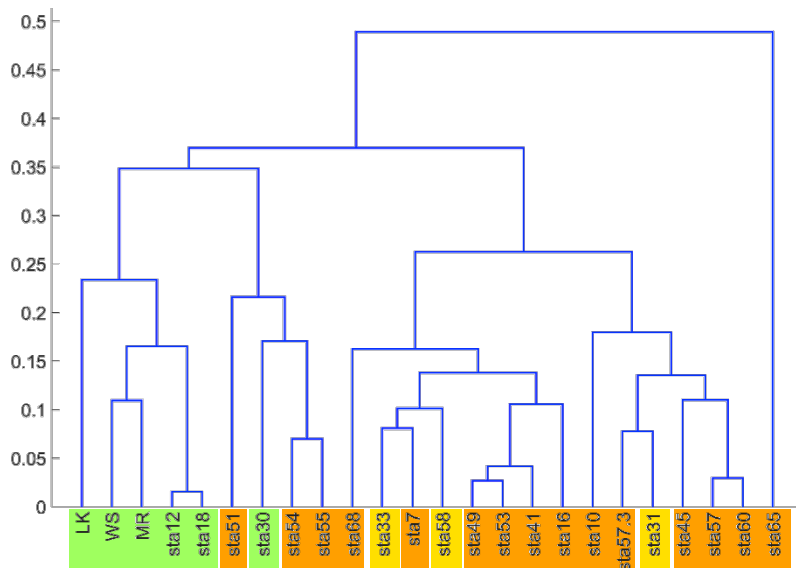
Seascape validation in south Florida waters

MARCH 2016

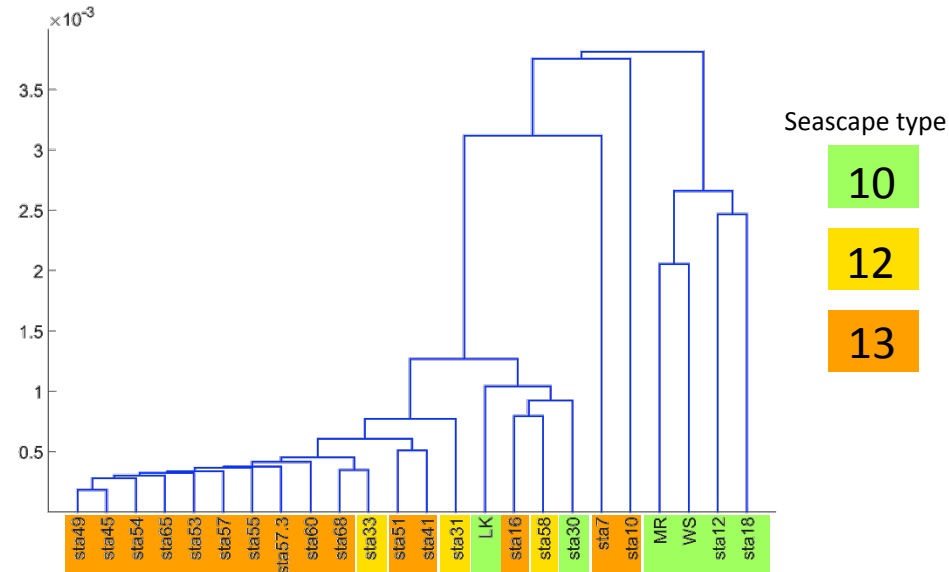


Seascape validation:
Seascapes show
distinct
phytoplankton
communities

Phytoplankton pigments (HPLC)



Phytoplankton absorption spectra (a_{phy})



eDNA Recovers a Wealth of Biodiversity from the Florida Keys NMS



Queen
conch



Moon jelly



Copepods



Spotfin
butterflyfish



Ornate
leaf
slug



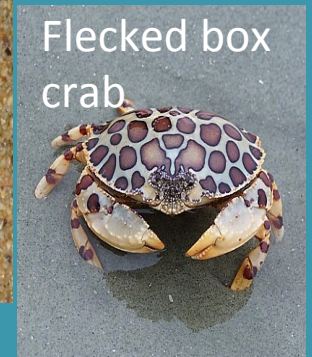
Caribbean
reef octopus



Chaetognaths



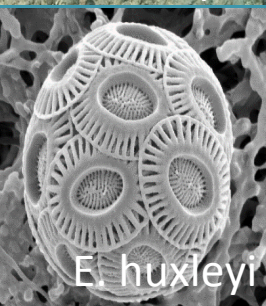
Peanut
worm



Flecked box
crab



Spider crab



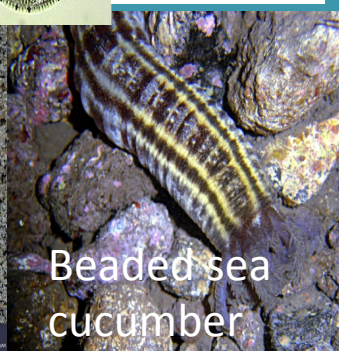
El huxleyi



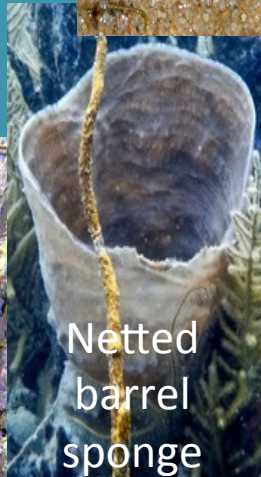
Acorn
barnacle



Diatoms



Beaded sea
cucumber

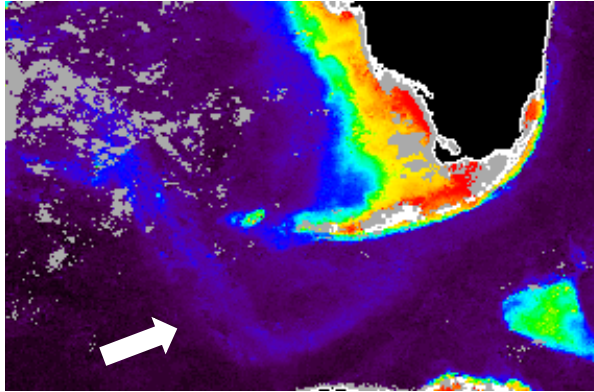


Netted
barrel
sponge



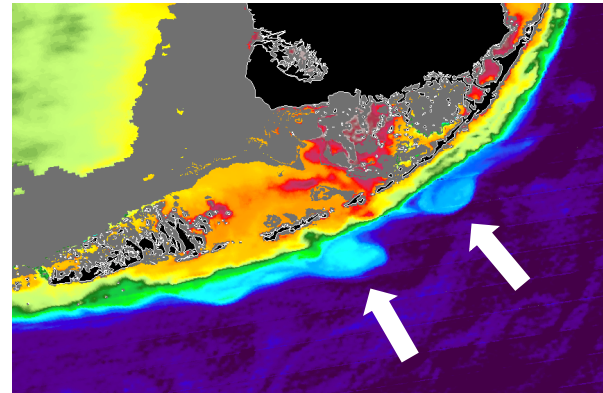
Green sea
turtle

Mesoscale and submesoscale features propagate through the Straits of Florida



Lower Keys

- mesoscale
- slow propagation
- long residence times



Upper Keys

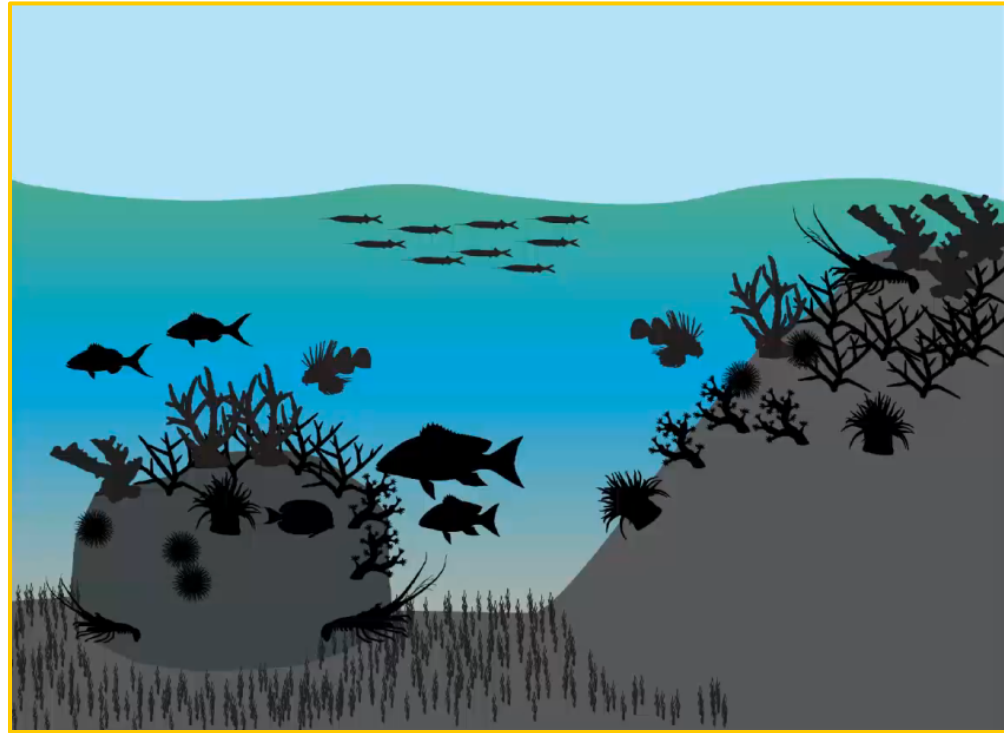
- submesoscale
- fast propagation
- short residence times

How does this dynamic oceanographic environment influence reef fish populations in the Florida Keys National Marine Sanctuary?

Florida Keys Coral Reef Ecosystem

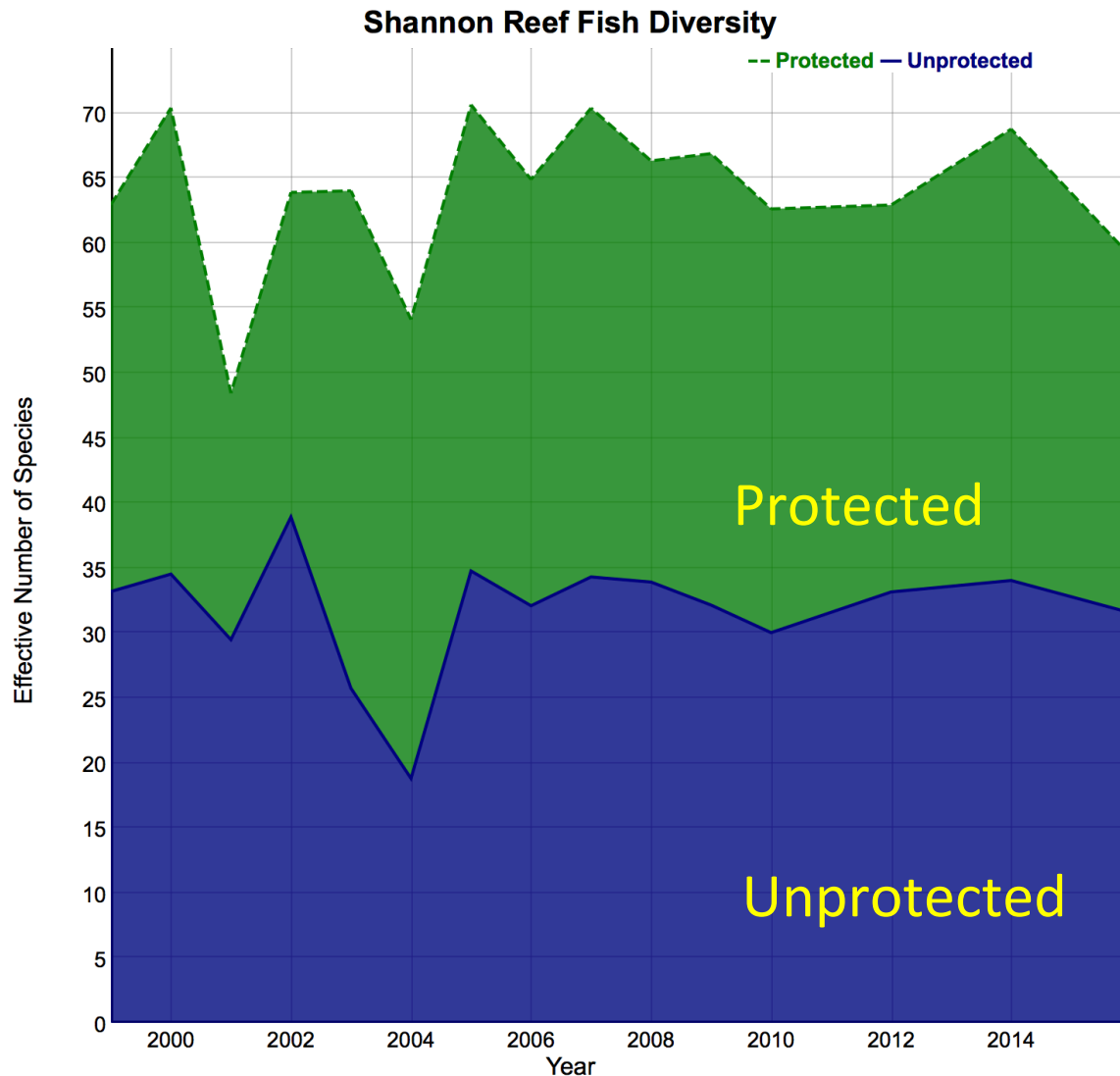
(Infographic approach)

1. Reef fish biodiversity
2. Trophic Groups (13)
3. Trophic level (4)
4. Exploited reef fish (9)
5. Stony corals
6. Sea fans
7. Sponges
8. Caribbean spiny lobster
9. Queen conch
10. Sea turtles
11. Black sea urchin



Florida Keys National Marine Sanctuary

Reef Fish Diversity

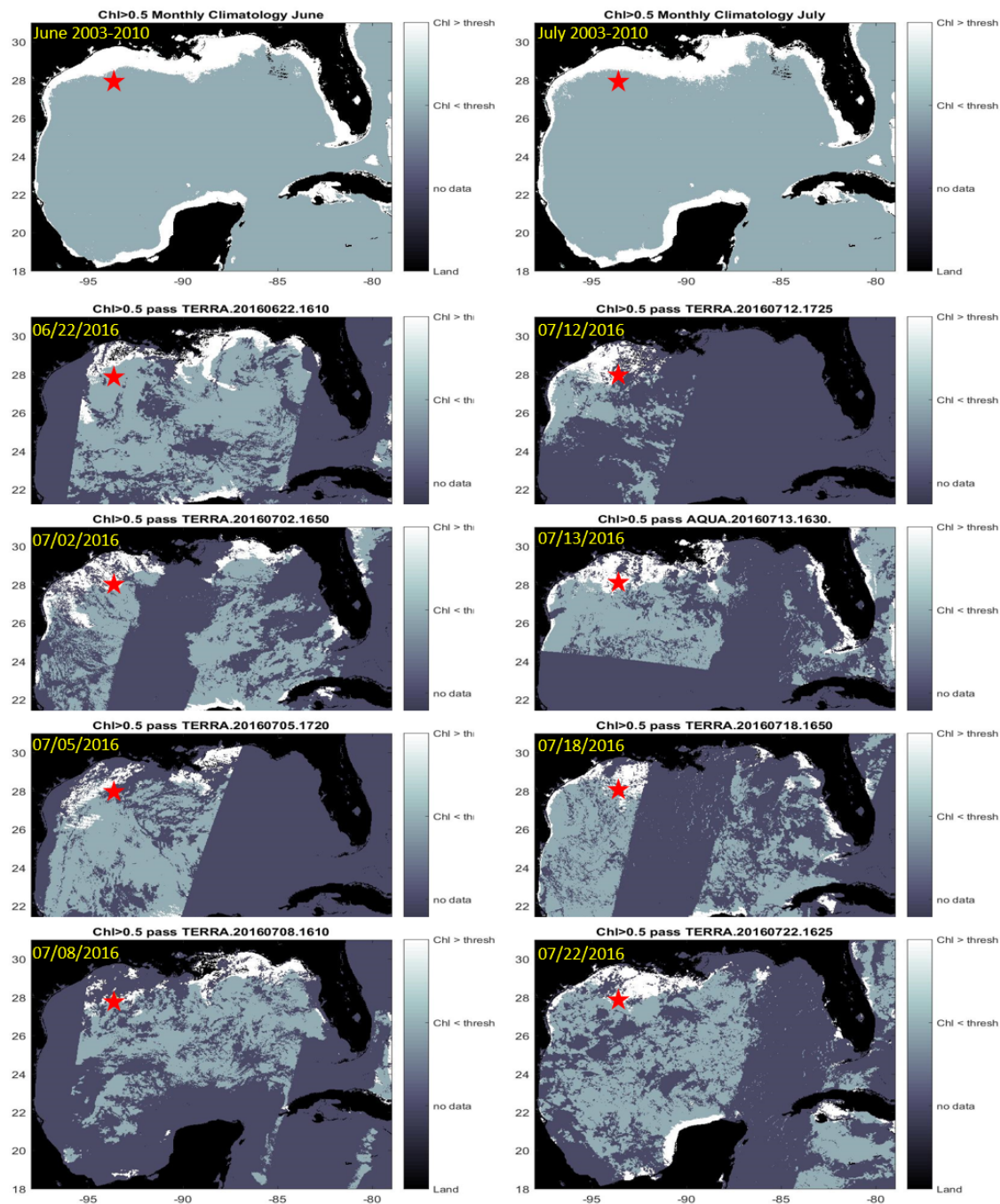


Flower Garden Banks:

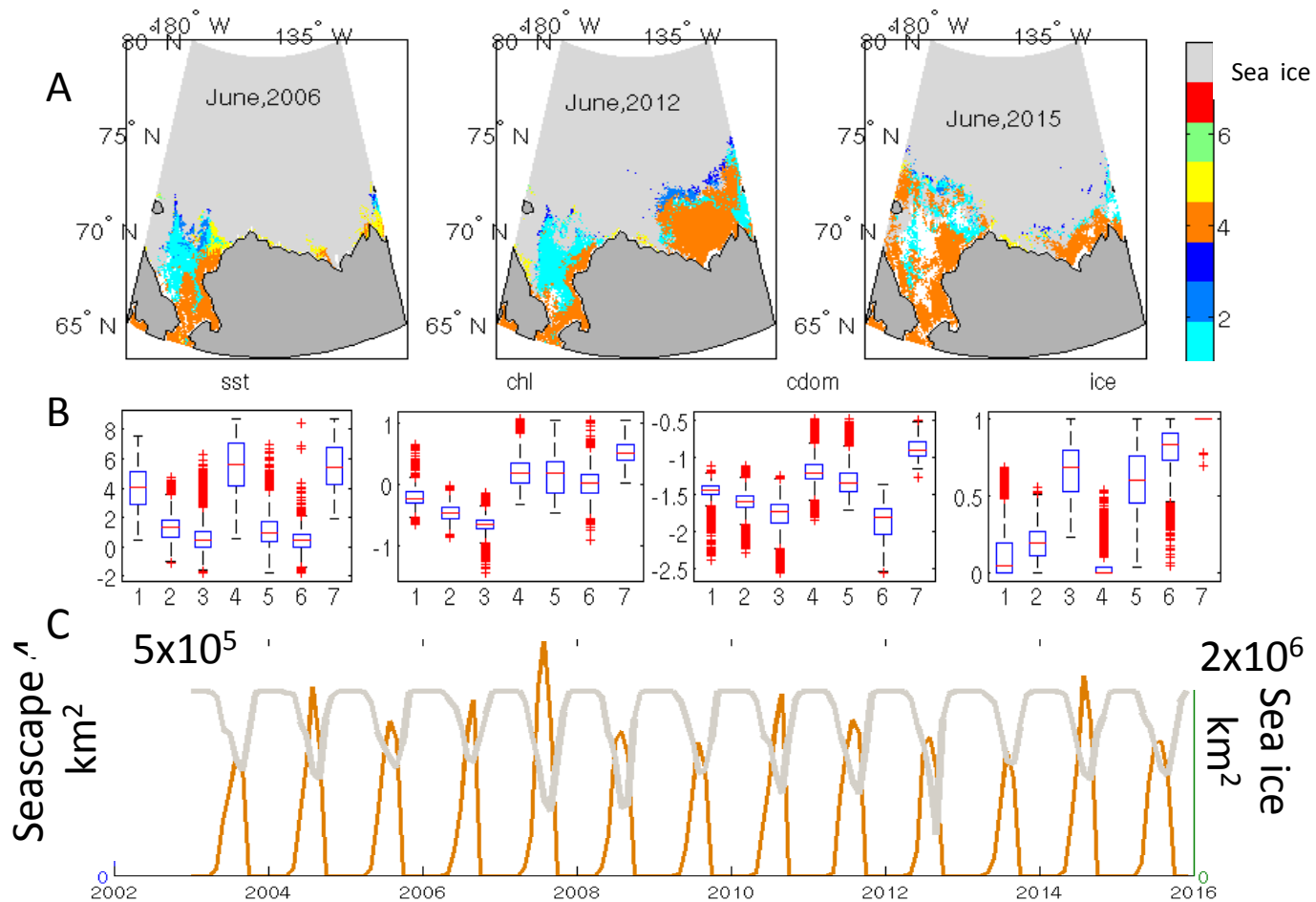
July 2016
Invertebrate
mortality event:

Coastal water
advection

- *collaboration with FGBNMS,*
- *Matthieu Le Hénaff (AOML)*

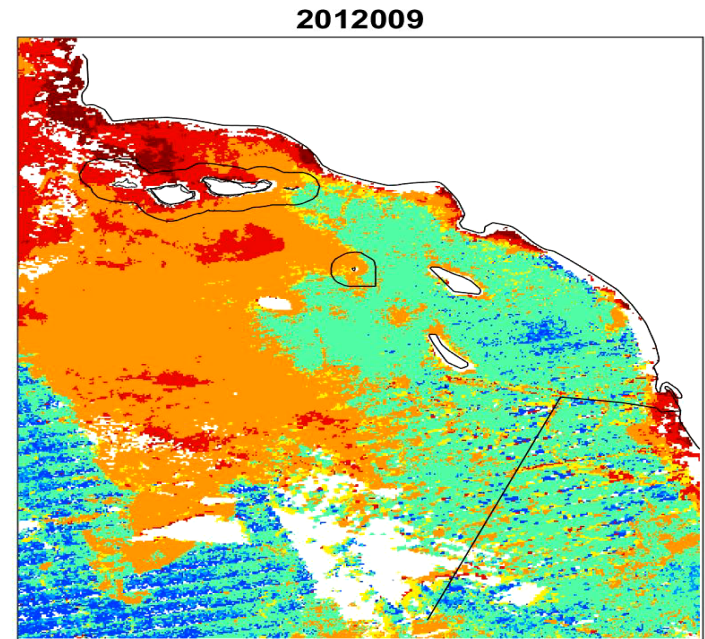


X-MBON: Alaska MBON Seascapes



X-MBON: Southern California Seascapes

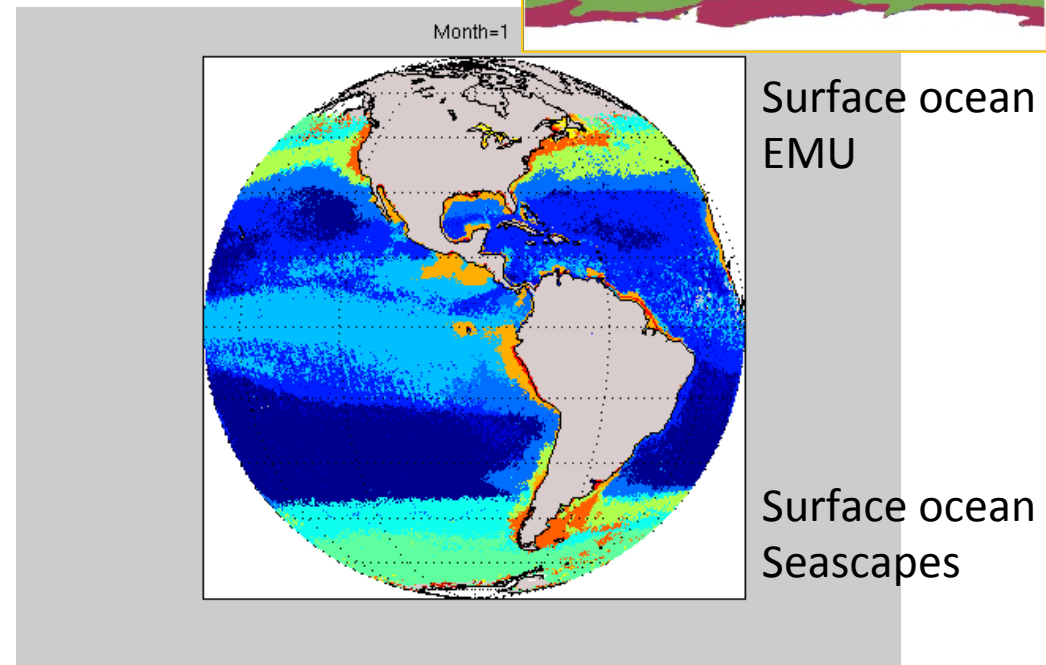
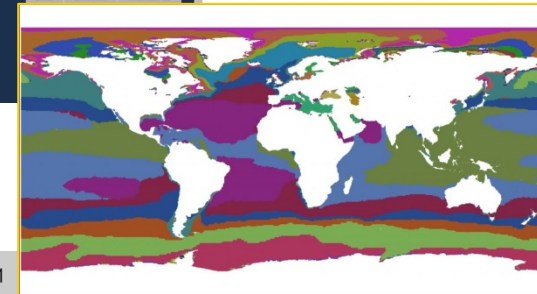
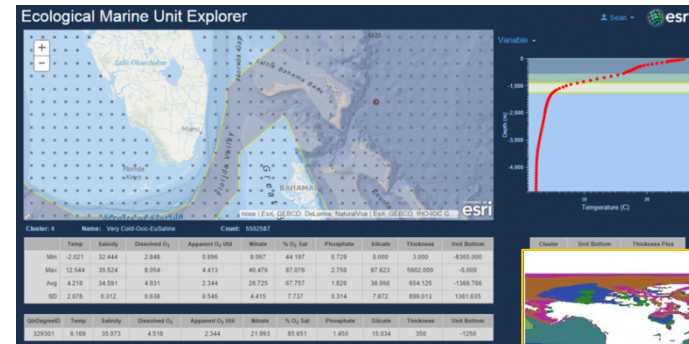
- Prototype classification completed for the Santa Barbara channel and SoCal Bight
- Thanks to Maria Kavanaugh and Dan Otis!



Regional to Global Seascapes

In progress/Next steps:

- Refine science questions
- Algorithms: HAB, acidification
- Automate data flow between NASA, USF, WHOI, IOOS DMAC / Axiom
- **COVERAGE:** CEOS Ocean Variables Enabling Research and Applications for GEO
- GEOBON and broader links:
 - [Link Ecological Marine Units/EMU \(USGS/esri\)](#)
 - Other partners/internationally

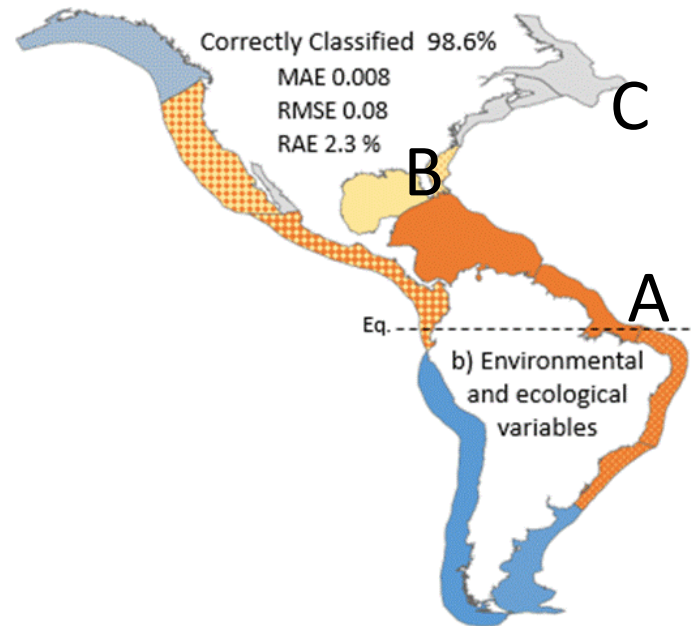


Example: diversity of fisheries and satellite seascapes (SST, CHL, primary productivity) in Large Marine Ecosystems (LME) of the Americas

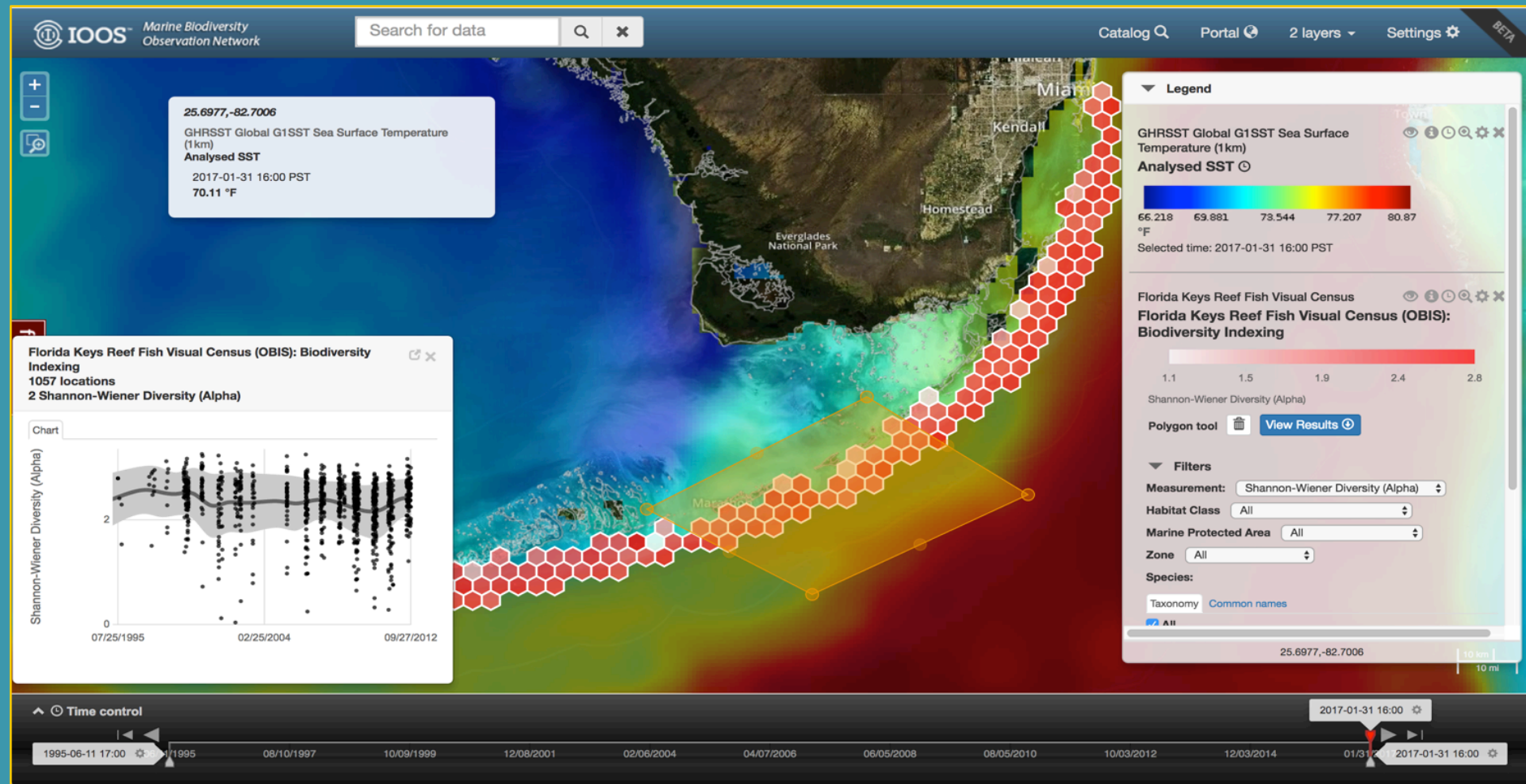
Results:

Three megaregions

Between 1982 and 2010, seven LMEs diversified their fisheries

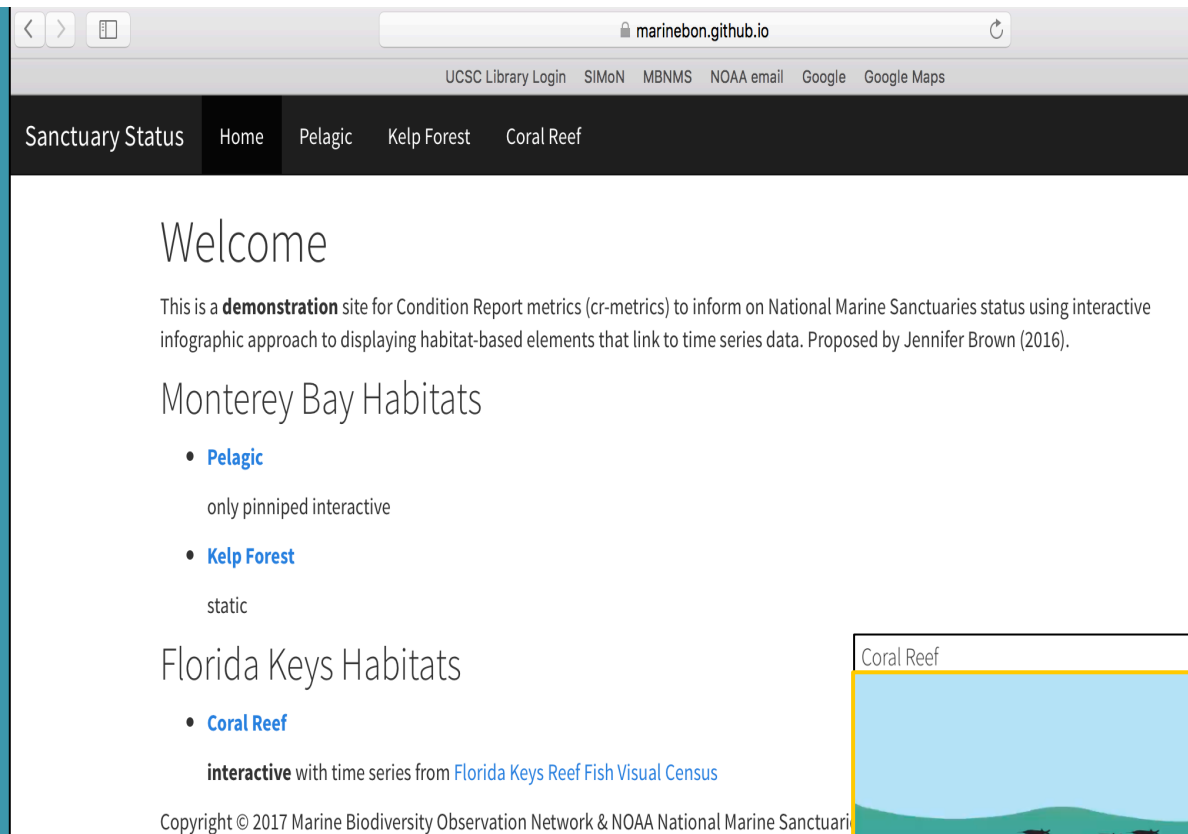


MBON Data Management and Data Visualization



Example: IOOS MBON portal
<http://mbon.ioos.us/>

Simplification: A Requirement from NMS -- MBON Interactive *Infographics* --



The screenshot shows a web browser at marinebon.github.io. The navigation bar includes links for UCSC Library Login, SIMoN, MBNMS, NOAA email, Google, and Google Maps. The main menu has tabs for Sanctuary Status, Home, Pelagic, Kelp Forest, and Coral Reef. The Pelagic tab is selected, displaying a 'Welcome' message and a description of the demonstration site. It lists 'Monterey Bay Habitats' with 'Pelagic' as the only pinniped interactive habitat. 'Florida Keys Habitats' are listed with 'Coral Reef' as an interactive habitat with time series data from the Florida Keys Reef Fish Visual Census. The copyright notice at the bottom reads: Copyright © 2017 Marine Biodiversity Observation Network & NOAA National Marine Sanctuaries.

Welcome

This is a **demonstration** site for Condition Report metrics (cr-metrics) to inform on National Marine Sanctuaries status using interactive infographic approach to displaying habitat-based elements that link to time series data. Proposed by Jennifer Brown (2016).

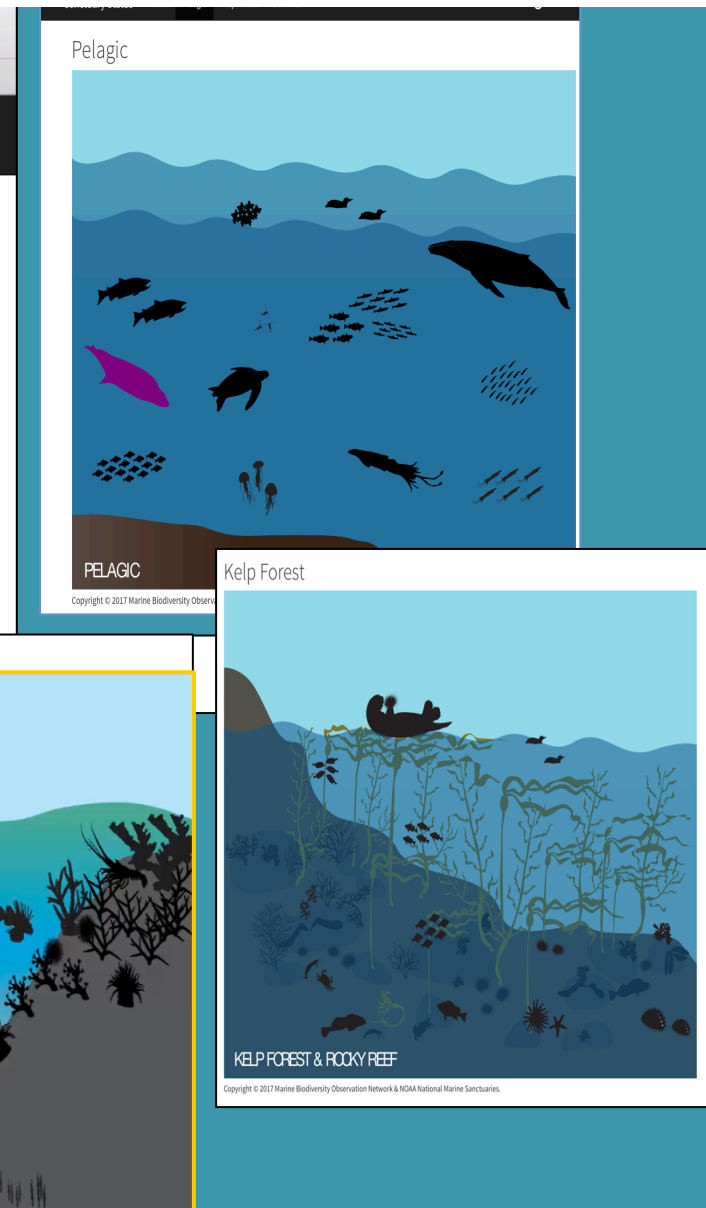
Monterey Bay Habitats

- **Pelagic**
only pinniped interactive
- **Kelp Forest**
static

Florida Keys Habitats

- **Coral Reef**
interactive with time series from [Florida Keys Reef Fish Visual Census](#)

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<https://marinebon.github.io/cr-metrics/pelagic.html>

Conceptual Model of Portal to *Status and Trends* Products

PELAGIC INDICATORS



KEY CLIMATE & OCEANOGRAPHIC DRIVERS

- Q1, Q13: Nitrogen: Phosphorus
- Q2: HABs - extent, duration, frequency
- Q3: Basin-scale indicators (MEI, NPGO, CUI)
- Q3: pH
- Q3: Sea surface temperature
- Q3: Dissolved Oxygen



KEY HUMAN ACTIVITIES

- Q2, Q13: Contaminants - levels in water, fish
- Q13: Shipping - levels
- Q13: Marine debris abundance
- Q15: # strandings/entanglements
- Q15: Commercial fishing activity level
- Q15: Recreational fishing activity level



Q7: Phytoplankton/Chl a
Abundance/biomass

Q10: At-sea seabirds
Species richness

Q8: Local nesting birds
Colony size & productivity

Q10: Phytoplankton
Taxonomic structure

Q8: Salmon
Abundance

Q8: Leatherback
Abundance

Q7: Key forage fish & invertebrates
Species abundance anomaly

Q8: Baleen whales
Local distribution & abundance

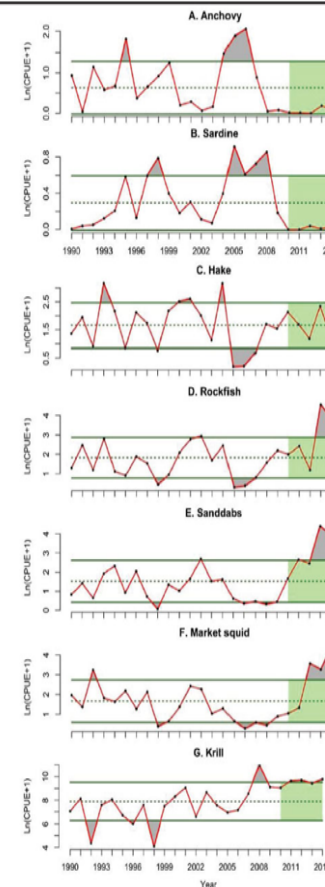
Q8: Pinniped
Pup production & growth

Q8: Gelatinous zooplanton
Relative abundance/biomass

Q10: Key forage
Diversity metrics

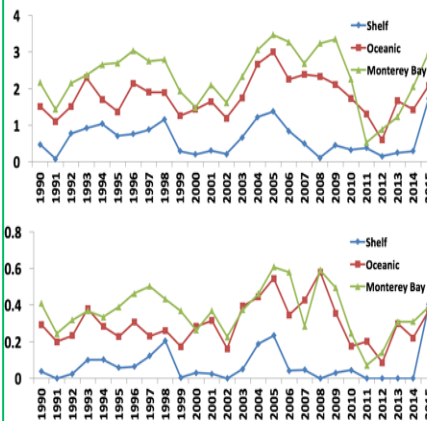
Q10: Midwater larval fish
Relative abundance/ biomass by group

Q9: Non-indigenous species
Density/biomass



Seven key pelagic forage groups for MBNMS from NMFS-SWFSC Rockfish Recruitment and Ecosystem Assessment Surveys as reported on CCIEA indicator website

"Forage" Richness and Diversity



(Santora et al. in review)

MBON

Marine Biodiversity
Observation Network

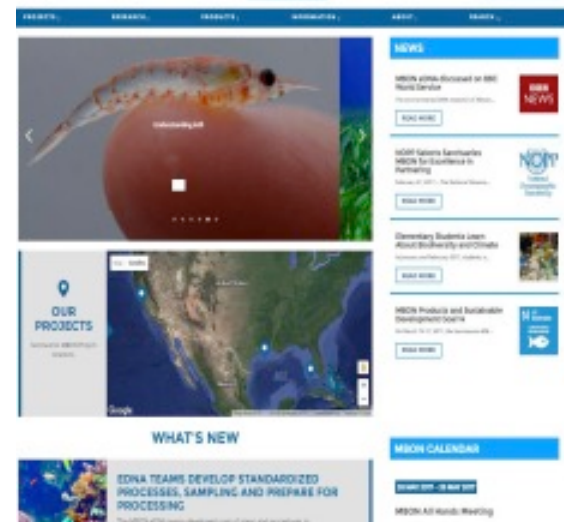
Communications & Outreach

*CJ Reynolds, Jennifer Brown,
Chris Simoniello, Mitch Roffer*

Engage users and support Products

- Quarterly Updates,
- Short videos,
- Pod casts,
- Sanctuaries MBON website,
- User oriented webinars and tutorials

Coming soon: Sanctuaries.marinebon.org



CENTER FOR
OCEAN
SOLUTIONS

eDNA Video



Story Map

Secrets in the Sea

Researchers are using environmental DNA to characterize marine life

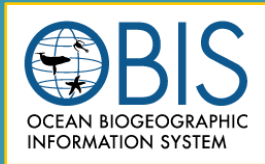


National and International Outreach

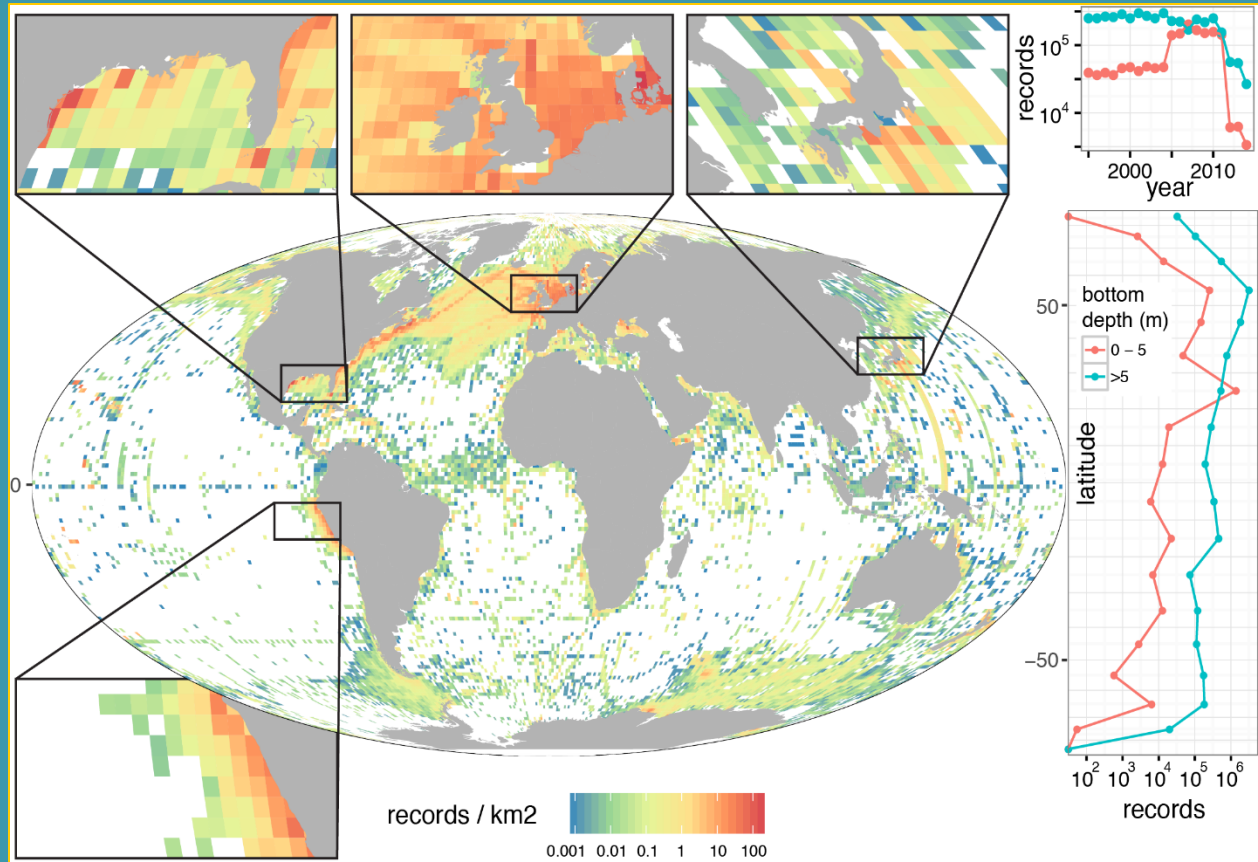
- Monthly GEOBON MBON webinars/telecon.
- Monthly X-MBON calls
- Maintain marinebon.org – national efforts/US projects
- Collaborate with GEO staff, support GEOBON MBON workgroup -- targeted engagement in key countries, expand webinar outreach
- Videos: e.g.
<https://youtu.be/jsNJKTUqNmQ>



The state of marine biodiversity monitoring



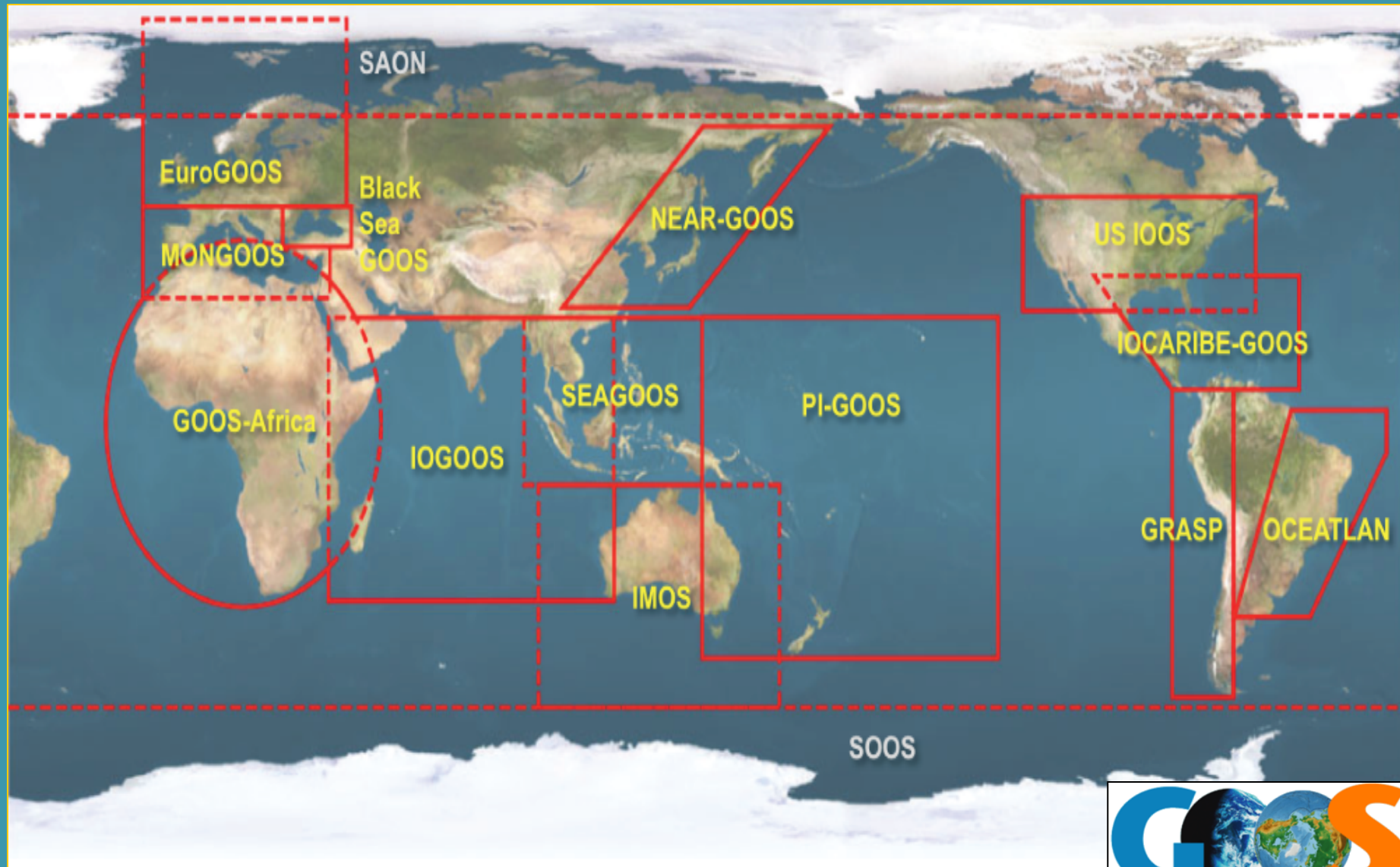
Enhance OBIS
open source code
for regional and
global
assessments

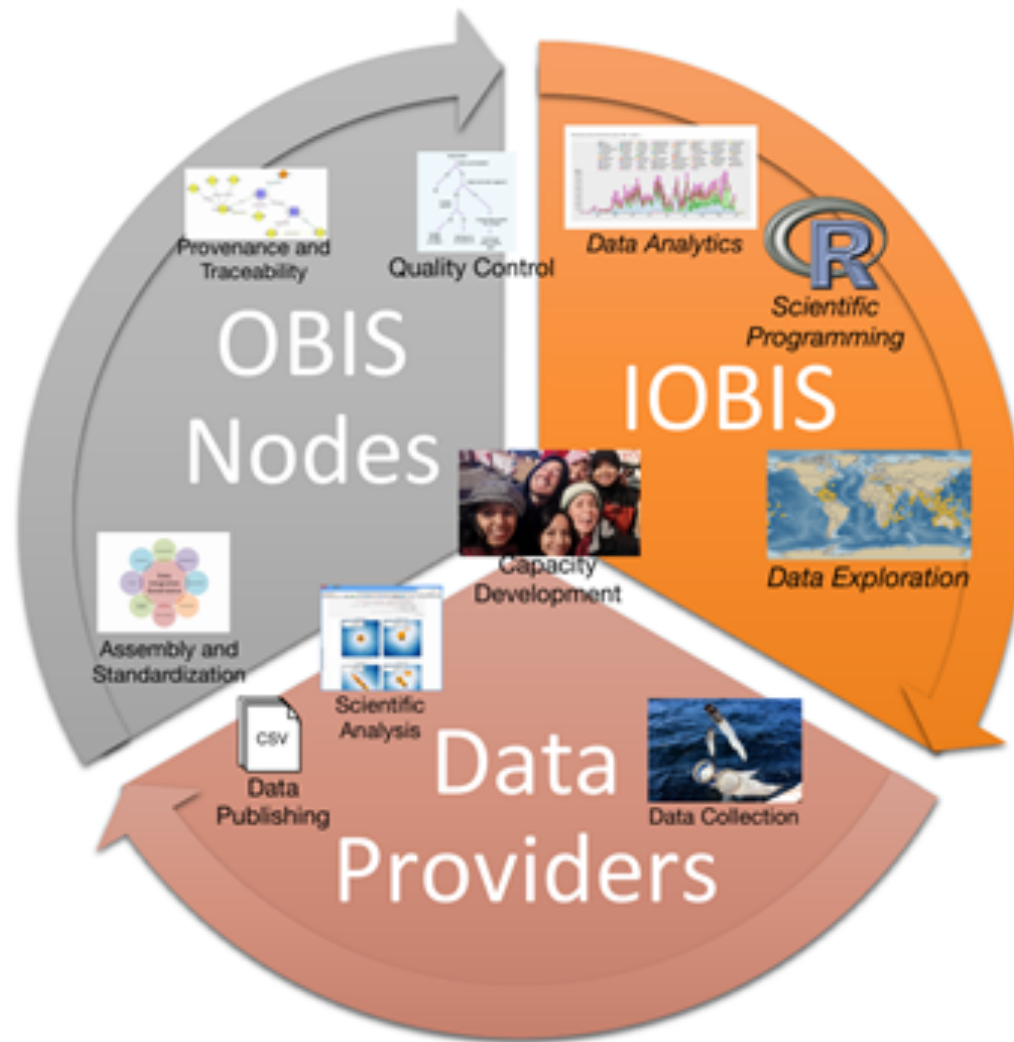


Near-surface taxonomic records (<20 m)

- Many areas have no records
- Less records in last 10 years:
lag in reporting data to OBIS

15 GOOS Regional Alliances

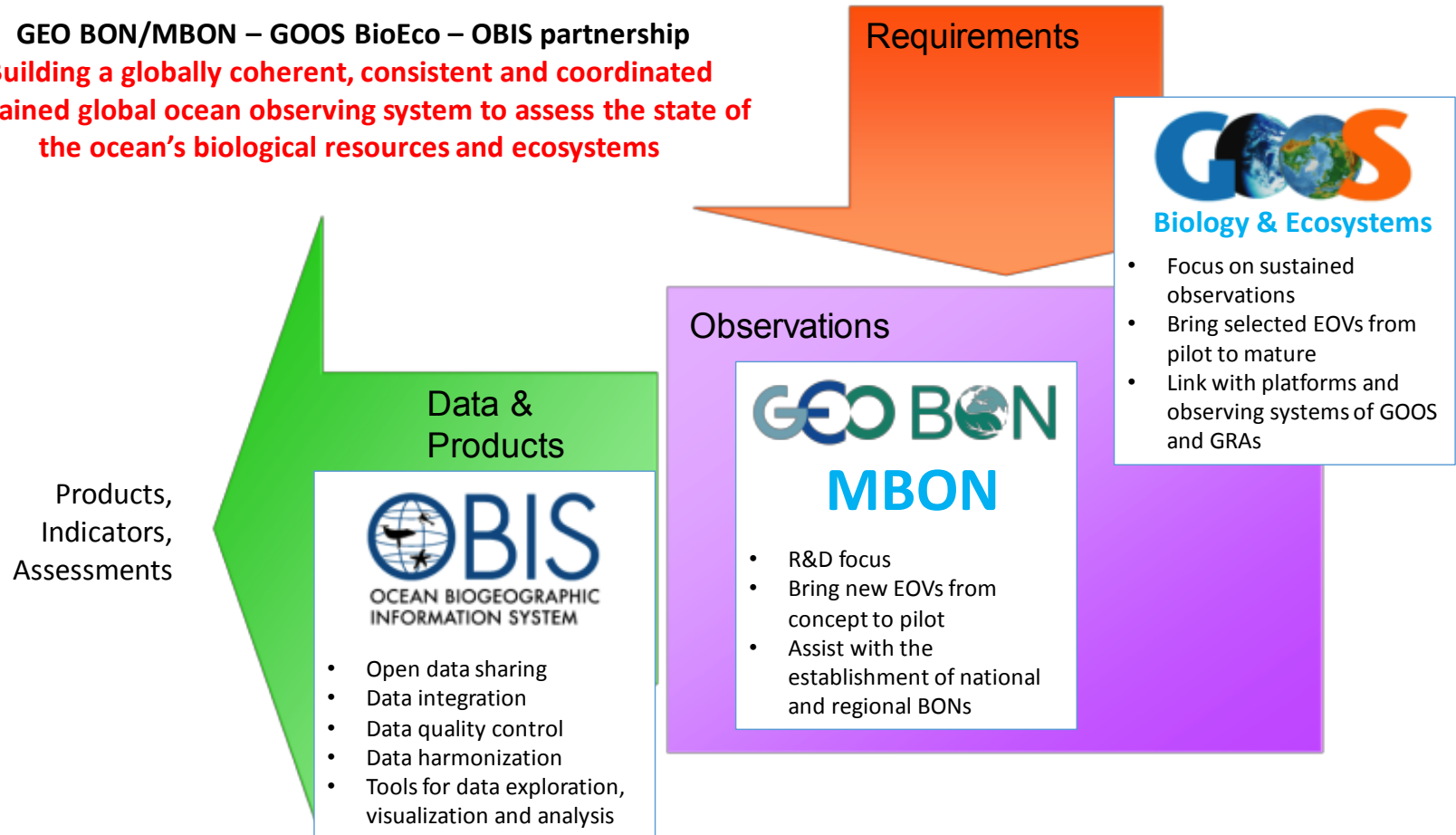




A Global Collaboration: OBIS + GOOS (IOC) and MBON

GEO BON/MBON – GOOS BioEco – OBIS partnership

**Building a globally coherent, consistent and coordinated
sustained global ocean observing system to assess the state of
the ocean's biological resources and ecosystems**



e.g.: <http://iobis.org/2016/12/15/goosgeobonobis/>

Ongoing/Developing Collaborations:

OBIS-GOOS-MBON

NSF OceanObs Network RCN

Animal Telemetry Network (ATN)

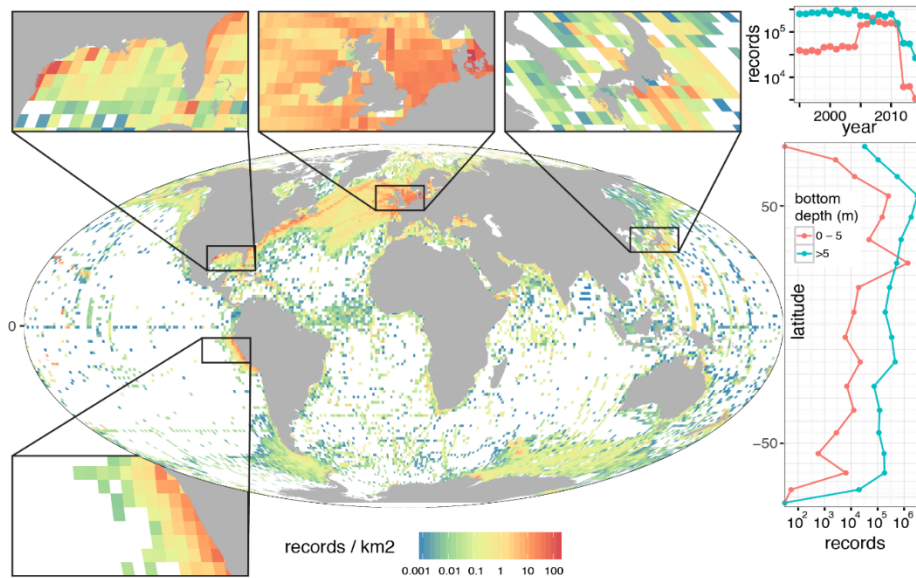
Ocean Acidification Network

Other IOOS RA's

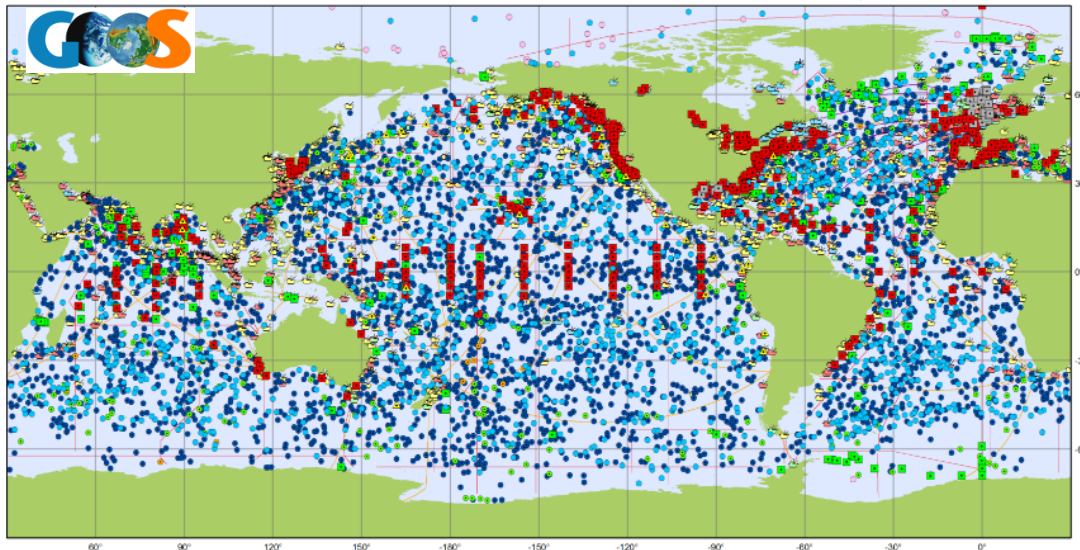
...



OBIS-GOOS-MBON Partnership: Belgium, Dec 2016



Present to Future



Main in-situ Elements of the Global Ocean Observing System

June 2016

GOAL:
Increase
observations of
marine life
building on GOOS,
OBIS, and other
networks:

- MarineGEO/Tennenbaum
- UNEP WCMC
- Americas (AmeriGEOSS)
- EuBON
- AsiaPacific
- Coral/GCRMN
- Africa
- CAFF (Arctic)
- National programs
- etc.

MBON Workshops – YR3

6 - 7 July, 2016, Leipzig,
Germany: All Hands
Meeting sessions on the
GEO MBON – GEO BON



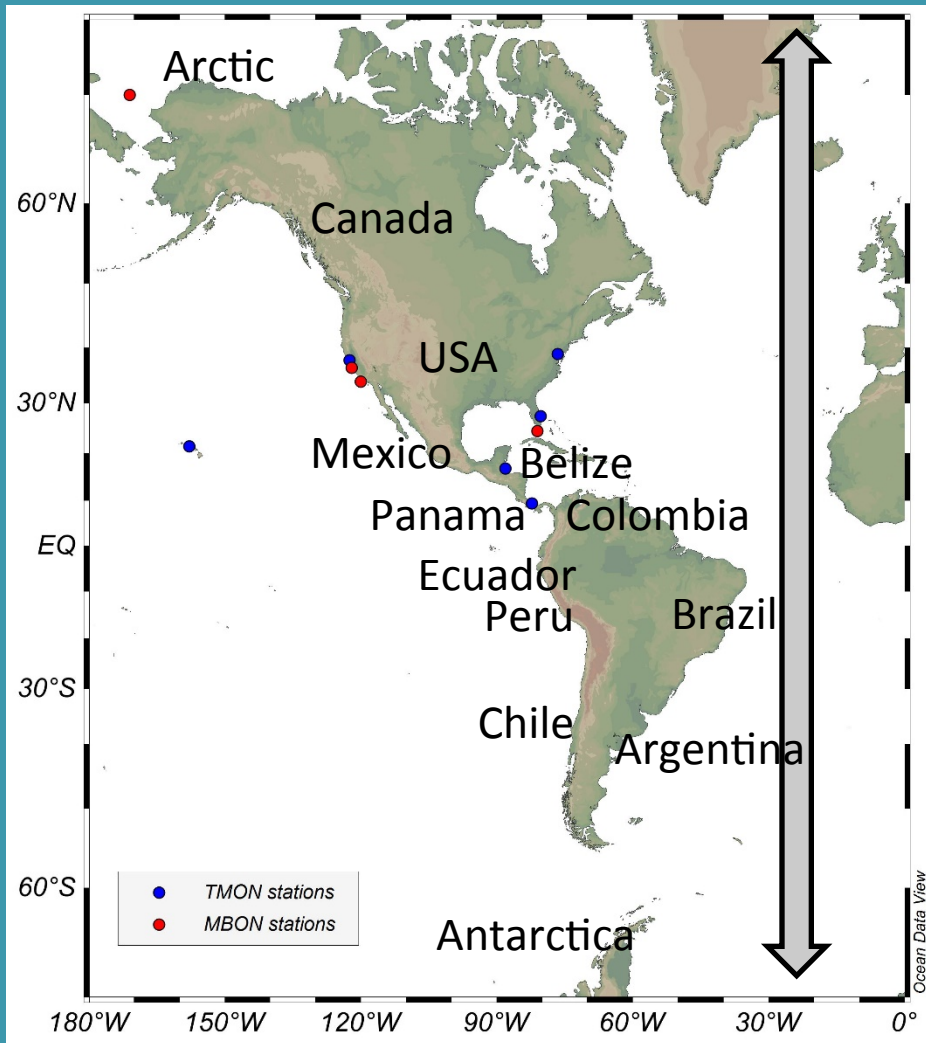
27-29 September, 2016, Playa
del Secreto, México: Pole-to-
Pole MBON in the Americas
Workshop – US MBON



15-17 March, 2017, St
Petersburg, Florida: SDG14
product development – US
MBON



Pole-to-Pole MBON of the Americas



- GEO Plenary, Mexico (2015)
- Convention of Biological Diversity (Montreal, Apr 24, 2016)
- GEO BON Open Science Meeting (Leipzig, Jul 4-6, 2016)
- Pole-to-Pole in the Americas Workshop (Puerto Morelos, Mexico, Sep 26-30, 2016)
- GEO-XIII Plenary (St Petersburg, Russia, Nov 9-10, 2016)
- Animal Telemetry Netw. – Mar'17
- AmeriGEOSS –Jul 2017 Costa Rica
- OBIS Workshops
- GEO Plenary-Oct 2017



13 Hands-on STEM Lessons:
Elementary, Middle, High
Standards cross-referenced
Science Festivals (4 annual)
Professional development
of educators
Outreach to minorities



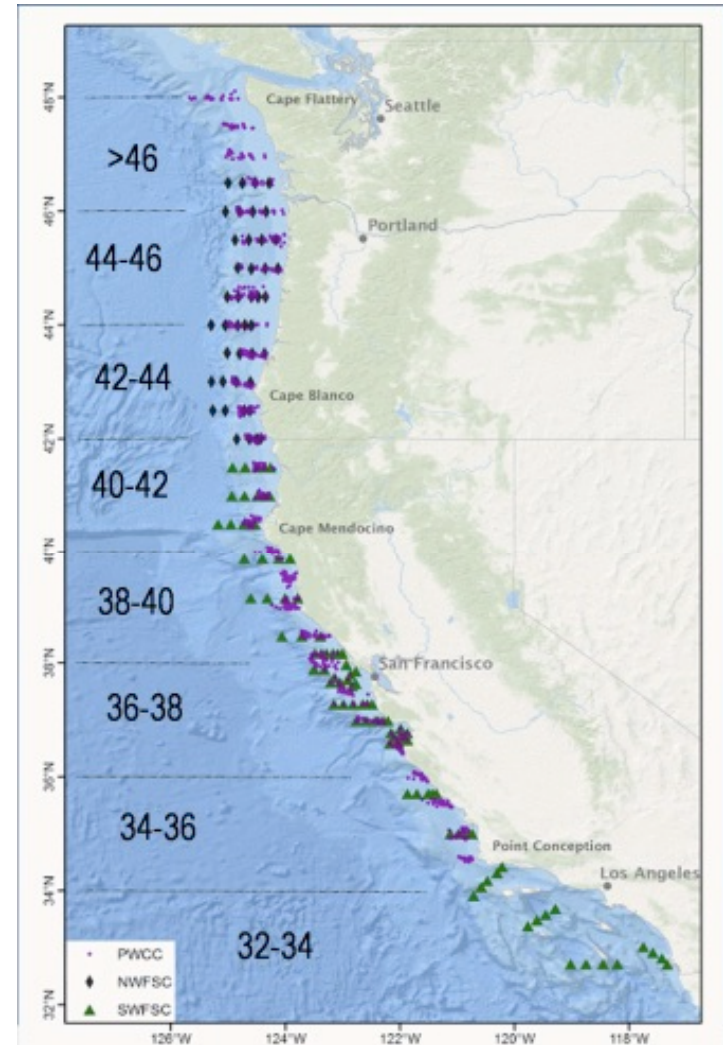
MBON

Marine Biodiversity
Observation Network

W Coast:

- Broaden spatial range
- Expand timeframe 13 y south of Mendocino, 6 y coastwide
- Add gelatinous zooplankton and krill to the species
- Integrate and evaluate with eDNA group (sampled on the 2016 & 2017 RREAS)
- Integrate with top predator surveys and associated diversity metrics
- Update the time series for each new year of RREAS sampling, catch data on ERDDAP, diversity time series on MBON data portal

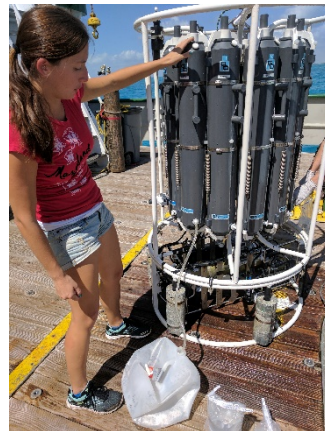
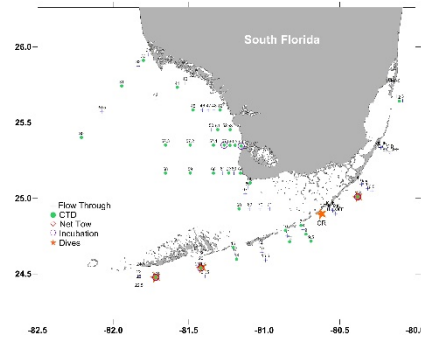
Next Steps



E Coast - Field campaigns YR3-4

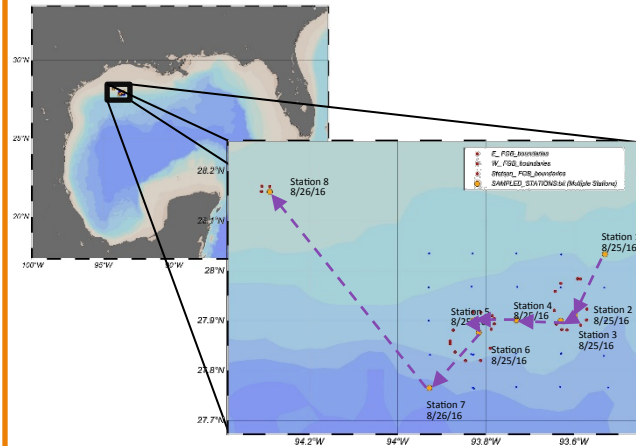
MBON - South Florida Program:

- Monthly large and small boat sampling



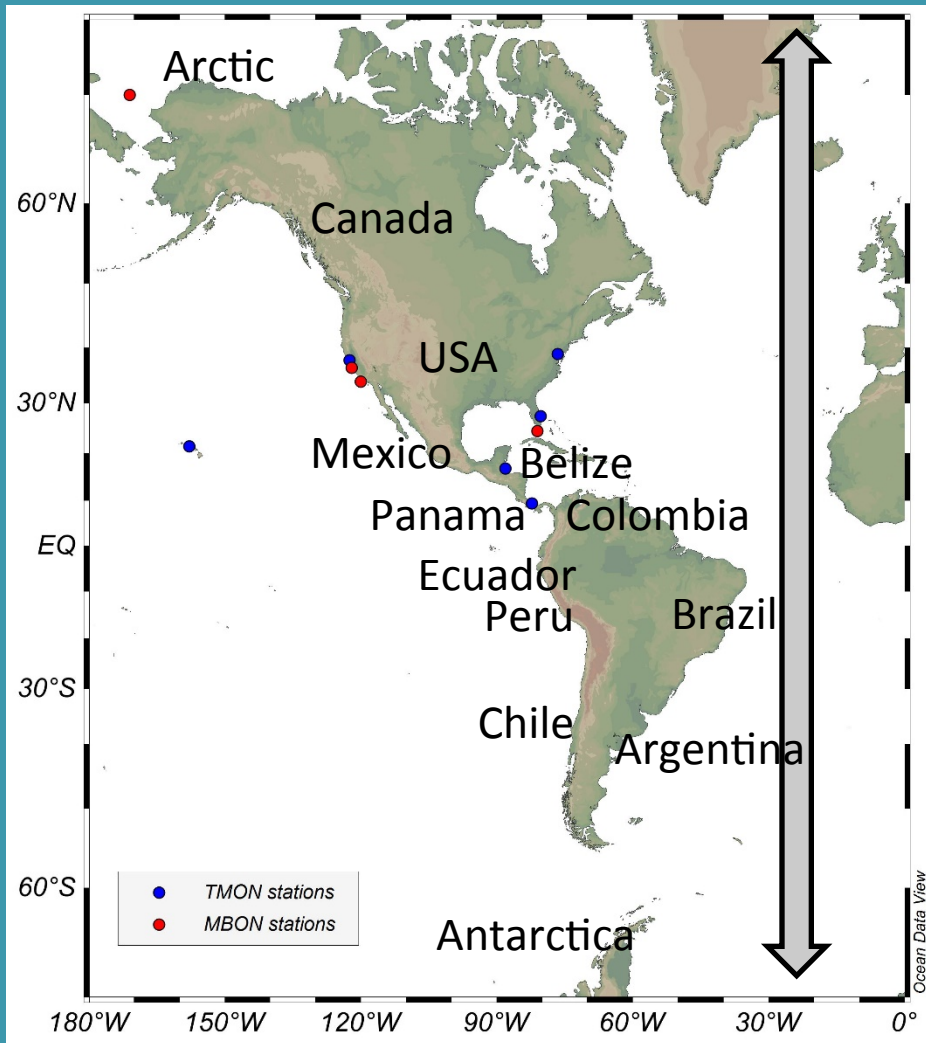
Flower Garden Banks NMS:

- Completed: August 24-26, 2016
- Upcoming: August 13-15, 2017



Coral spawning eDNA sampling

Pole-to-Pole MBON of the Americas



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SDG14
Interactive
web-based
tool



Acronym	Full name	Key activity
CBD	Convention on Biological Diversity	Aichi Targets
IMO	International Maritime Organisation	Protection of biodiversity and detection of invasive species
IUCN (WCPA, SSC)	International Union for the Conservation of Nature	World Commission on Protected Areas, Species Survival Commission
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora	Protection of biodiversity
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services	Assessments of biodiversity



SUSTAINABLE DEVELOPMENT GOAL 14

Conserve and sustainably use the oceans, seas and marine resources for sustainable development



10 targets that require scientific information and capacity building on biodiversity

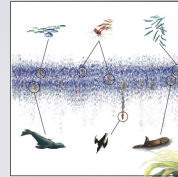
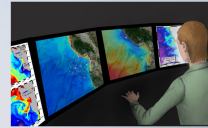
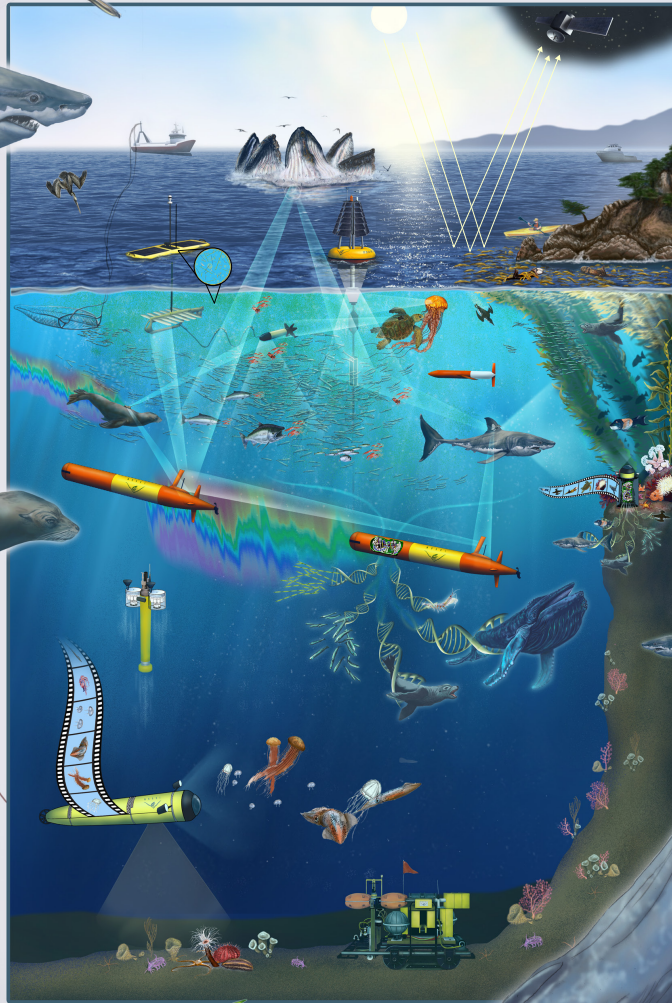
Successes:

- **Conceptual framework for collaborative MBON:**
 - Academic entities
 - NOAA programs, State government, international (GEO BON, IOC/GOOS, SBSTTA/CBD)
 - In conversation with several NGOs: MedPAN (Assoc. of Mediterranean Marine Protected Areas managers), Mexican Fund for the Conservation of Nature, etc.
- **eDNA: collection and extraction methods tested**
- **Satellite-based, dynamic *seascape* products: automated pipeline for input data in place for several MBON regions of interest**
- **Biodiversity field monitoring program implemented in both Sanctuaries**
- **MBON data used to update Monterey Bay NMS Condition Report**
- **Engaging in SDG 14 process**
- **Established solid partnership with GOOS and OBIS**
- **Engaging in AmeriGEOSS and GEO BON**
- **Making links: NOAA *ocean acidification* program, NOAA *Omics*, State and Federal fisheries & environmental monitoring, NSF LTER (Everglades), IOOS and other observation programs**
 - IOOS GCOOS has funded a Doctoral fellowship at USF to work MBON-LTER-SFP

Challenges:

- **Development of data management system & visualization tool**
 - **Identifying and understanding datasets**
 - **Transition to a permanent archive**
 - **Operational & research utility**
 - **Engage other monitoring programs to enroll data**
- **eDNA validation at different trophic levels: cost**
- **Curation and permanent archive of biological datasets from various sources:**
- **Communications flow on news and outreach**
- **Integrating the MBON observations into the FKNMS Condition Report**
- **Coordination of myriad moving parts with partners and X-MBON projects**
- **Building critical international partners and linkages**
 - **GEO BON Working Groups**
 - **Pole-to-Pole**
- **SDG 14 product acceptance internationally**
- **Operational MBON: path to sustainability not clear**

Observing Life in the Sea



Sanctuaries MBON Co-Investigators:

-Frank Muller-Karger (carib@usf.edu)

-Francisco Chavez (chfr@mbari.org)

The US Sanctuaries MBON Team

GEO BON MBON co-chairs:

-Frank Muller-Karger (carib@usf.edu)

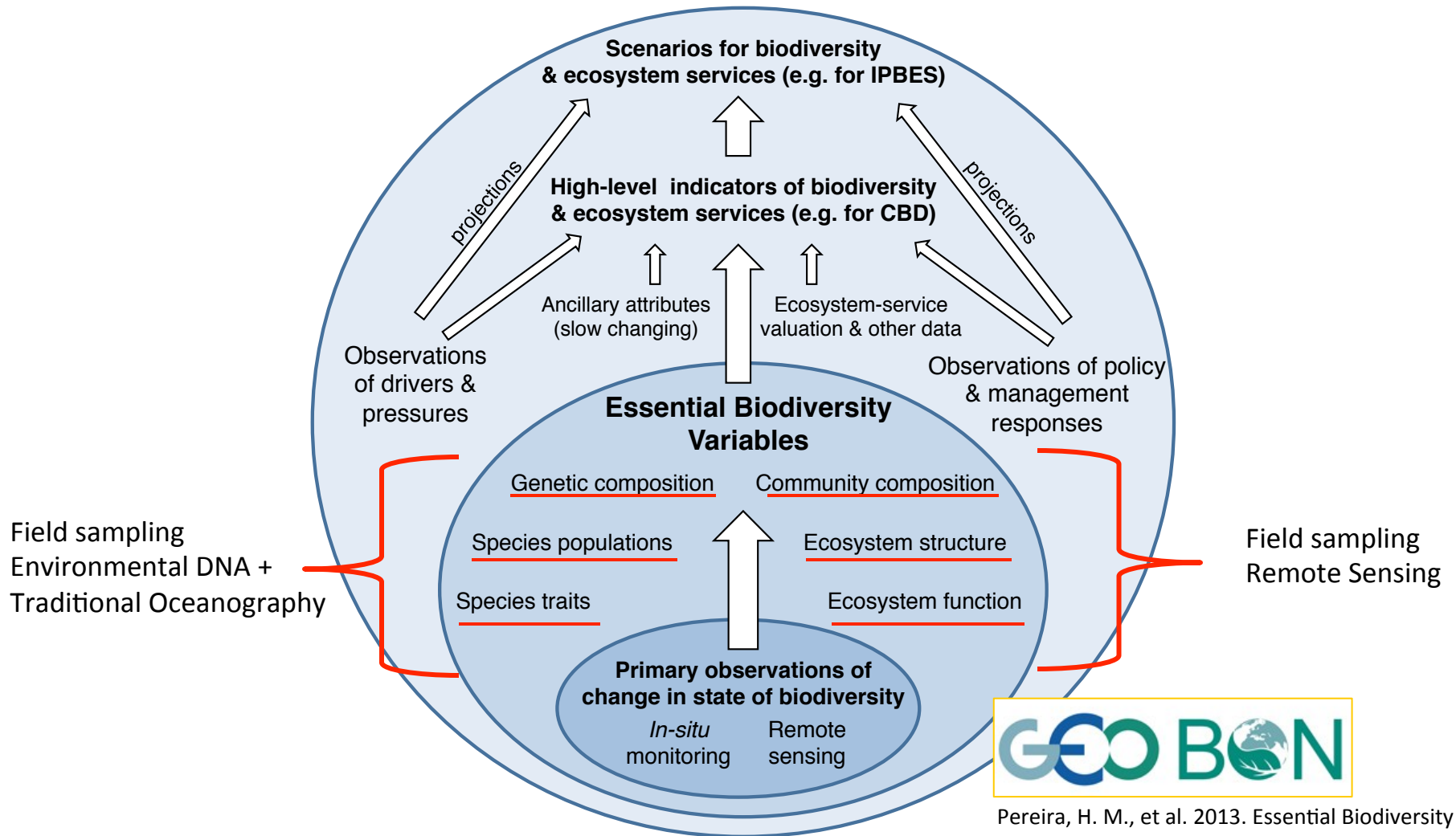
-Isabel Sousa Pinto (ispinto@ciimar.up.pt)

-Mark Costello (m.costello@auckland.ac.nz)

MBON

Marine Biodiversity
Observation Network

Essential Biodiversity Variables (EBV)



Pereira, H. M., et al. 2013. Essential Biodiversity Variables. Science. Vol. 339. 277-278.

Outline

- Advancing the MBON framework
- Sanctuaries MBON
 - Title: National Marine Sanctuaries as Sentinel Sites for a Demonstration Marine Biodiversity Observation Network (MBON)
 - Milestones and progress
 - MBON priorities
 - eDNA
 - Seascapes
 - Integration
 - data management and accessibility,
 - MBON sustainability (identifying new users and partners)
- X-MBON activities
 - Pole to Pole MBON in the Americas
 - AMBON, SBC MBON, TMON, GEO BON
 - UN Sustainable Development Goals (SDG14)
- Outreach and Communications
- Challenges